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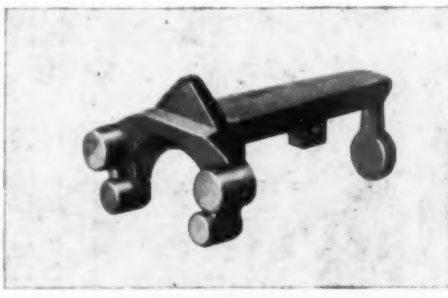
Aluminium Bronze Die-castings

By A Special Contributor.

The special qualities of aluminium bronze are beauty, strength, and permanency. Its application in the form of die-castings, when many parts are required of intricate design, is now more fully appreciated. In this from a high degree of strength and reliability is combined with low cost.

ALTHOUGH known prior to 1860, it is only during comparatively recent years that aluminium bronze has been appreciated by engineers and designers. It has attracted attention because of its remarkable properties, which include high tensile strength, excellent resistance to alternating fatigue, and also because of its resistance to corrosion, particularly to attack by sulphuric acid. The valuable properties of this alloy indicated possible applications for it in die-cast forms, but initial experiments, employing known technique, as employed with alloys having lower casting temperatures, showed the necessity for different technique. Many difficulties were encountered, largely due to the higher tempertture necessary and to the effect the fluid metal had upon the die. It was recognised that delay in development was probably due to lack of information on the behaviour of the alloy when cast in chill moulds, which created some doubt regarding the reliability of the castings. Considerable research work has, however, been carried out since the initial experiments, as a result of which many of the difficulties formerly associated with the manufacture of die-castings have been overcome.



By courtesy of Fry's Metal Foundries Ltd.

Fig. 1.—Typical aluminium bronze die-casting. Weight 1 oz.

Die-castings in aluminium bronze are now being produced in all weights from 1 oz. to 10 lb. and upwards, of the most intricate and diverse shape, within the limits ± 0·005 in. The illustrations, Figs. 1 and 2, show 1 oz. and 5 lb. castings respectively. Further, due to careful control in composition of the alloy used, its remarkable properties are being maintained with a regularity comparable with any other die-cast metal or alloy. To-day, aluminium bronze die-castings can claim to be reliable castings, and suitable for heavy duty conditions.

In the widest application of the term, aluminium bronze contains anything from 2 to 16% of aluminium, the remainder being copper, together with small percentages of iron, manganese, or nickel; the majority of the alloys in use, however, contain from 5 to 11% of aluminium. With less than 7% aluminium, the alloy displays characteristics more resembling copper, while with aluminium contents exceeding 12% the alloy develops brittle tendencies. Alloys containing from 10 to 12% aluminium have been found more resistant to attack by dilute sulphurous acid than more complex compositions, the addition of small percentage of iron to a 90-10 alloy increases the resistance to attack by dilute sulphuric acid; iron also improves the alloy's resistance to attack by several other acids, while the addition of nickel increases resistance to corrosion by sea-water. Some polynary alloys resist attack by specific media better than binary or ternary compositions. The difference in resistance to corrosion of different alloys, according to R. J. Anderson,[1] is not great, and he states that the various compositions used are more resistant to attack by many agents that are corrosive to other engineering materials.

In its simplest form, aluminium bronze, containing 90% copper and 10% aluminium, has properties not unlike those of Swedish "Dannemora" iron. It has a tensile strength of 30 to 35 tons per sq. in., and an elongation of 15 to 20% in 2 in. It can be hardened, drawn, and normalised, like steel, and shows corresponding changes of structure related to changes of physical properties. Heat-treatment technique similar to that for steel, giving much the same range of improved results. For instance, a 10% aluminium alloy hardened at 900° C., quenched in water and subsequently drawn to a temperature of 300° C., will show a tensile strength of 48 tons per sq. in., an elastic limit of 20 tons per sq. in., and an elongation of 2% in 2 in. If, on the other hand, the drawing temperature is raised to 800° C., the tensile strength will be 38 tons per sq. in., with elastic limit 17 tons per sq. in. and elongation of 34%.

The addition of small percentages of other metals, such as nickel, iron, manganese, etc., confer further valuable physical properties, opening up fields of utility for aluminium bronze in practically every industrial sphere. The effect of the addition of iron up to 4%, for instance, increasing the maximum proof stress and the tensile strength of the die-cast alloy.

It is important to note that, within a very appreciable range of temperatures the mechanical features of the aluminium bronzes, among others their hardness, remain practically unaffected. Further, they do not scale. These features give to these bronzes a marked superiority over steel in certain applications.

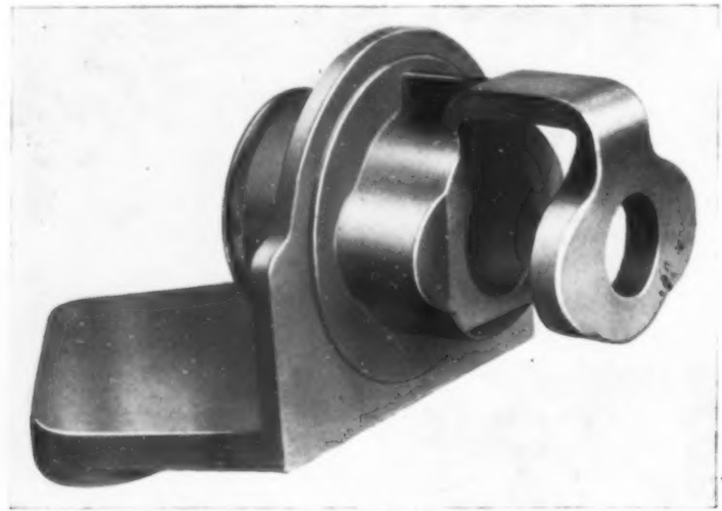
Another important feature which these alloys possess is the fine hard crystals evenly embedded in a softer matrix. The structure of a typical alloy after heat-treatment,

1 R. J. Anderson, "Aluminium Bronze: A Corrosion-resistant Alloy." METALLURGIA Vol. 2, No. 8, pp. 57-9.

indicates that these alloys possess anti-friction qualities. Actually the coefficient of friction of a typical alloy is 0·022.

Continued success in the production of aluminium bronze die-castings is due to improved technique, and, although difficulties are encountered, with due consideration to the design of a proposed casting, modification of the composition to meet special requirements, careful control of casting temperature, correct location of runners, and proper design of the dies, these difficulties are minimised, and reliable castings are produced.

Die-casting in any metal is only a commercial proposition when the number of castings of similar design is such as to warrant the cost of a die. The larger the number required, the lower will be the die cost per casting. When numbers are necessary, and there is a likelihood that a die-casting will be a good proposition, the designer could profitably obtain the advice of a die-casting specialist. Slight modifications in design can have a considerable difference, not only on the cost of a die, but in simplifying an otherwise difficult job. This is particularly advisable in die-castings in aluminium bronze, because the range of castings made is smaller than with, say, aluminium die-castings. An expert can suggest modifications that do not affect the purpose for which the castings are required, and yet make the process a commercial proposition for their production. The composition of alloys used should be under rigid metallurgical control, as only by so doing can the required qualities be produced with that regularity modern industry demands. It is essential, for instance, to use electrolytic copper and high purity aluminium. They should be melted under the strict supervision of a responsible metallurgist. This is important in order to obtain the results necessary when definite stresses are required. The formation of aluminium oxide should be guarded against, as it is likely to remain permanently suspended in the metal, in which case the strength of the metal is materially reduced.



By courtesy of Fry's Metal Foundries Ltd.

Fig. 2.—Typical aluminium-bronze die-casting, weight 5 lb.

The correct casting temperature is an important consideration. The metal should be of such a temperature as will completely fill the mould. Quantities of gases are emitted from the metal during solidification, and efforts should be made to cause the metal to set as soon as the mould is filled. Obviously, when castings vary in sectional thickness the temperature of the metal will be governed by the thinnest section, and in some cases the alloy needs to be considerably superheated to enable it to completely fill a mould. Casting temperatures must vary according to the design of the work, and are usually within the range 1,150–1,300° C. Apart from the temperature of the metal, the most important factor operating against the complete filling of the mould is trapped air. The proper venting of a die is, of course, essential.

In view of the high shrinkage of the aluminium bronzes—between 1·9 and 2·4%, according to aluminium content—runners should be placed on the thicker parts, so that they can act as feeders. The metal should be poured fairly rapidly, and the casting immediately ejected.

Probably the chief difficulties in the production of aluminium bronze die-castings are associated with the dies. Due to erosion and high temperature of the casting metal, the dies have a relatively short life. Close-grained grey iron is the best all-round material for aluminium bronze, the chief precaution being to keep the phosphorus content low, since the compound with iron formed melts at about 950° C., resulting in the local breakdown of the structure. Phosphorus is, therefore, best kept below 0·3%. Cast iron stands up well to the solvent action of the high-temperature alloy better than many steels. No "dressing" is required on the face of the die. The thickness of the die depends on the job in hand, and may vary from ½ in. to 1 in. Such moulds or dies should, with careful handling, last for at least 10,000–15,000 castings—this depends entirely on the design of the work, as with complicated work nothing like these numbers would be obtained. The quantities required to be produced, and the intricacies of the design determine whether more expensive but more serviceable materials can be used. Genders, Reader and Foster[2] state that high-speed and stainless steels are more satisfactory than carbon steels, but they do not approach in serviceability the high-chromium alloy steels introduced specially for heat-resisting purposes. Thus, in some cases, where long runs are required, the body or form is "let in" the cast iron in the form of a block consisting of a heat-resisting alloy steel.

The useful lives of cores vary considerably. Sometimes they are almost entirely immersed in the hot molten alloy, and they have to withstand this in addition to torsional stresses at high temperatures. Deterioration occurs by erosion, by the welding-on of the cast metal and by tensile stresses set up in liberating the hot core after each casting. They must be made of heat-resisting steel, and highly polished. Large cores are sometimes made from phosphorus-free iron or semi-steel.

The problem of a suitable die-metal for many kinds of intricate castings is not yet adequately solved. The treatment of parts by calorising the heat-resisting iron or steel,[3] in contact with materials containing aluminium, in an inert atmosphere, has been tried with varying results. This process gives the iron or steel a higher resistance to oxidation in air at high temperatures.

Each individual casting is a law unto itself with regard to the speed of pouring and temperature. Generally speaking, the pouring is quite rapid, while the lower the pouring temperature at which a complete casting can be obtained the better; this saves the die from "spot-heating," just as the metal enters the die, and also prolongs the life of the cores. The metal is usually melted in an ordinary plumbago crucible, fired with town's gas, coke, or oil fuel.

The following advantages should be borne in mind when considering the possibilities of aluminium bronze die-castings for a wide variety of uses, when quantities make it a commercial proposition :—

1. It can be die-cast within limits of 0·005 from a weight of 1 oz. to 10 lb. and over.
2. Its remarkable resistance to nearly all kinds of corrosive media, whether in the atmosphere, some acids, sea-water, and gases.

2 R. Genders, C. R. Reader, and V. T. S. Foster, "Die-casting of Copper-rich Alloys, *J.I.M.*, 1928.
3 *Rev. Met.*, 1926, 23, 219.

(Continued on page 200.)

Aluminium Sheet Production

By Robert J. Anderson, D.Sc.

Part IX.—The Hot Break-down Operation.*

Practice at the hot-mill in rolling aluminium ingots to slabs, lubrication of ingots and cooling of rolls, slab thicknesses, and man-power requirements, are discussed.

IN working out standard roll sets for rolling slabs it is convenient to draw up charts which indicate the dial readings for successive passes. This is a matter of simple arithmetic, due allowance being made for spring and play in the mill, side-spread, and other variables. Thus, the theoretical sets may be calculated, corresponding to the reductions and extensions desired. Then, in actual rolling, measurements of the slabs may be made during the processing and proper allowance factors determined for given conditions.

Due to wear in the journals and strain in the mill the pointer of the dial may get out of alignment with the numbered divisions, and hence incorrect readings are given for the roll sets. It is advisable to make adjustment at least daily. This is done by running the upper roll down so that it is just in contact with the lower roll, and adjusting the pointer so that it reads zero. The mill may be equipped with a safety device to prevent contact of the rolls and hence damage to the mill by accident or carelessness. Such a device may be designed to prevent the upper roll from moving closer to the bottom roll than ⅛ in. If the safety setting is accurate the upper roll is lowered as far as it will go, and the dial pointer is set at number 6¼ (where one division equals 0·02 in.), this corresponding to a roll opening of ⅛ in.

TABLE III.

SCALE FOR HOT ROLLING 3¼ in. BY 14 in. BY 24 in. INGOTS TO VARIOUS WIDTHS.

Width of Slab to be. In.	Dial Pointer Stands at Number.							Thickn'ss to which Ingot is Rolled. In.
	First Pass.	Second Pass.	Third Pass.	Fourth Pass.	Fifth Pass.	Sixth Pass.	Seventh Pass.	
14	25	18	50	20	31½	—	—	0.500
15	25	**30**	20	50	20	31¾	—	0.500
16	25	**40**	30	5	25	34	—	0.450
17	25	**47**	30	8	28	36¾	—	0.400
18	25	**4**	38	12	28	38¾	—	0.375
19	25	**10**	40	12	28	39	—	0.375
20	25	**15**	45	15	28	39¼	—	0.375
21	25	**50**	**19**	45	15	28	39½	0.375
22	25	**5**	**23**	48	16	28	39¾	0.375
23	25	**8**	**27**	8	28	40	—	0.375
24	25	**10**	**31**	10	30	40	—	0.375
25	25	**10**	**34**	10	30	40¼	—	0.375
26	25	**12**	**37**	12	30	40½	—	0.375
27	25	**15**	**40**	12	30	40¾	—	0.375
28	25	**15**	**43**	14	30	41	—	0.375

NOTE.—Ingot is cross-rolled on the passes where the dial numbers are set in bold-face type.

An empirical scale for hot-rolling ingots measuring 3¼ in. by 14 in. by 24 in. is shown in Table 3; the range of widths covered is 14 in. to 28 in., the thickness being ⅜ in., except in the widths 14 in. to 17 in. Table 4 gives a scale for hot-rolling ingots of the same size to slabs ¼ in. thick and 20 in. to 46 in. wide. The dial numbers refer to the numbers on the dial at which the pointer should stand before making the pass indicated. The numbers set in bold-face type in the tables indicate that the partly broken slab is cross-rolled on the pass—*i.e.*, rolled in a direction at 90° with the direction of the first pass. The first pass is made by hitting the ingot end-on—*i.e.*, presenting the 3¼ in. by 14 in. face to the rolls. Cross-rolling is at right angles to that face—*i.e.*, perpendicular in a horizontal plane to the 3¼ in. by 24-in. face, referring to the unbroken ingot. These tables refer to a specific mill where the dial was divided into 50 parts, and one revolution of the dial was equal to a vertical movement of 1·000 in. for the upper roll. Confusion will be avoided if it is understood that the dial runs backwards. Thus, in rolling a slab ⅜ in. thick by 28 in. wide (*cf.* Table 3, last line), the first pass is made with the pointer of the dial standing at 25, this corresponding to a roll set of 2·5 in., the screw having been turned up 2½ times. The second pass is made with the pointer at 15; the upper roll was lowered 10 numbers, or 0·2 in. The third pass is made with the pointer at 43; the upper roll was lowered 22 numbers, or 0·44 in. (150 = 15; 50 − 43 = 7; 15 + 7 = 22).

Sundry examples might be given to explain more fully the details of the passing, but the principle of the operation will be understood from the tables and the foregoing discussion.

TABLE IV.

SCALE FOR HOT ROLLING 3¼ in. BY 14 in. BY 24 in. INGOTS to ¼ in. THICK AND VARIOUS WIDTHS.

Width of Slab to be. In.	Dial Pointer Stands at Number.							
	First Pass.	Seond Pass.	Third Pass.	Fourth Pass.	Fifth Pass.	Sixth Pass.	Seventh Pass.	Eighth Pass.
20	25	**50**	**15**	50	25	40	45	—
21	25	**50**	**19**	50	25	40	45¼	—
22	25	**5**	**23**	5	28	40	45½	—
23	25	**8**	**27**	8	28	40	45¾	—
24	25	**10**	**31**	10	30	40	45	—
25	25	**10**	**34**	10	30	40	46¼	—
26	25	**12**	**37**	12	30	42	46	—
27	25	**12**	**40**	14	30	42	46¼	—
28	25	**15**	**43**	15	30	42	46½	—
29	25	**15**	**46**	16	30	42	46¾	—
30	25	**15**	**48**	16	30	42	47	—
31	25	**10**	**35**	**49½**	20	34	44	46¼
32	25	**10**	**35**	**1**	22	34	44	46½
33	25	**12**	**40**	**3**	22	34	44	46¾
34	25	**12**	**40**	**5**	24	38	45	—
35	25	**12**	**40**	**6¼**	25	38	45	—
36	25	**12**	**40**	**8**	26	38	45¼	—
37	25	**12**	**40**	**9½**	28	38	45½	—
38	25	**15**	**45**	**11**	30	40	45½	—
39	25	**15**	**45**	**12**	30	40	45½	—
40	25	**15**	**45**	**13**	30	40	45½	—
41	25	**15**	**45**	**14**	30	40	45½	—
42	25	**15**	**45**	**15**	30	40	45½	—
43	25	**15**	**45**	**16**	30	40	45½	—
44	25	**15**	**45**	**17**	30	40	45¾	—
45	25	**15**	**45**	**18**	32	40	45¾	—
46	25	**15**	**45**	**19**	32	40	45¾	—

NOTE.—Ingot is cross-rolled on the passes where the dial numbers are set in bold-face type. Two passes are made on the last set in the case of slabs rolled to 31 in. and wider.

Disposition of the Slabs.

After a slab has been rolled it is disposed of suitably, depending on the subsequent processing. If there is no continuous mill in the plant the slabs are laid off in a pile to cool. Slabs may be piled on small buggies, or on other transport equipment for movement to shears. Ingots are ordinarily rolled in lots, the number to a lot depending in part on the size of the order, and in part on the available transport equipment and capacity of scales for weighing. After a lot has been hot rolled, the head catcher will mark with chalk on the face of the top slab, in the pile, the lot number, size, and other identification. Fig. 3 shows the catchers in the act of laying-off a finished hot-rolled slab. Slabs for flat sheet go directly to the slabbing mill, or to the slab shears if shearing is required. Slabs for coil production go to the stock shears, unless rolled directly on a continuous mill. Slabs for flat sheet may, of course, be roughed on a wide continuous mill.

* (*Continued from page* 151, *September issue.*)

At one plant hot slabs from the break-down operation are pushed on a roller table directly from the hot mill to an eight-stand continuous mill, hwere they are run down to about $\frac{1}{8}$-in. thick. The slabs enter the latter mill at about 250° C. This is the only case where aluminium is worked hot in sheet rolling other than in the hot break-down operation.

As has been mentioned previously, it is desirable that slabs come off the hot mill as flat as possible, or at least they should be flattened while hot if curled or out of level. The curling of slabs is caused by lack of lubrication, too-hot rolls, rolls of different diameters, and misalignment (in a vertical plane) of the rolls. Flatness may be promoted by giving two passes to the slab on the last roll set, the final pass then being made with practically no draft.

Lubrication and Cooling.

In aluminium hot-mill practice proper provision must be made for lubricating the surfaces of the ingots and for cooling the rolls. Methods employed for accomplishing these objects vary in different mills, but in tonnage plants it is desirable that lubrication and cooling be combined and continuous. An effective method of continuously lubricating and cooling consists in spraying the roll surfaces with a water emulsion of a soluble oil, the water acting as the coolant and the oil as the lubricant. In a later article the lubrication and cooling of bearings and roll necks will be considered.

The object of lubricating the ingot surface is essentially to improve performance at the hot mill—*e.g.*, prevent the slabs from sticking to the rolls, increase the tendency of the rolls to " bite," and prevent the slabs from curling. Roll cooling is necessary in order to promote continuity of operation, reduce the consumption of lubricant, and increase the life of the rolls. So far, the ideal combined lubricant and coolant has not been developed ; the medium which most closely fulfils the bulk of requirements is a water emulsion of a soluble oil. Practically any oily or greasy substance is effective in preventing the slabs from sticking to the rolls, thereby also reducing the tendency to curl. On the other hand, oils are not effective coolants, in comparison with water, because of their relatively low specific heats. Oils may be disregarded as cooling agents in aluminium hot-mill practice. Lubrication of the ingot should not be too generous, or rather the lubricant should not be too oily (slippery), otherwise difficulty is had in the rolling. Thus, if the surface is too oily it is difficult to start the ingot through the rolls, and, even after the rolls have bit, the ingot may suddenly turn at right angles (or cornerwise) and roll through in the wrong direction. This behaviour may be experienced with water-oil emulsions when the oil content is too high. Kerosene may be thrown on the ingot to improve the bite.

Fig. 3.—Catchers laying-off a finished hot-rolled slab.

If aluminium ingots at about 450° C. are passed on a cold mill, using an oil lubricant on the metal, the rolls heat and shortly become so hot that the lubricant flashes. Presently, with the lighter lubricants, a sheet of flame breaks out on the passage. This is not only dangerous to the mill-hands, but also substantially destroys the lubricating value of the oil, causes charring on the slab, and, still more, raises the temperature of the rolls. The result is that sooner or later, depending on the lubricant and other factors, rolling must be stopped in order to cool the rolls. Or else the rolling may be carried out more or less continuously, but at such a slow rate that no effective production is obtained.

Aside from troubles with the lubricant and reduced rate of output a high roll temperature has a very harmful effect on roll life, particularly in the case of chilled cast-iron rolls. Or, more precisely, repeated heating to a higher temperature, followed by cooling (to room temperature or about 100° C.) has much more deleterious effect than repeated heating to a lower temperature followed by cooling. The thermal fatigue resulting from the heating and cooling, and the differential expansions of the internal mass and the annular face rim in the case of chilled cast-iron rolls, presently leads to cracking of the roll surfaces and, ultimately, to breakage. The condition of checking and irregular surface fissuring is referred to as " fire-cracking." A fire-cracked roll is undesirable, first, because it imparts its crack pattern to the slab, and, second, because it has started to fail and may break in the housings, thereby damaging the mill. Fire-crack impressions on a slab may persist more or less throughout the subsequent rolling. As mentioned previously, with bradly cracked rolls, it may be advisable to allow extra stock so that the impressions may be " worked out." Fire-cracking can evidently not be prevented in chilled cast-iron rolls, but its onset may be considerably deferred by proper cooling.

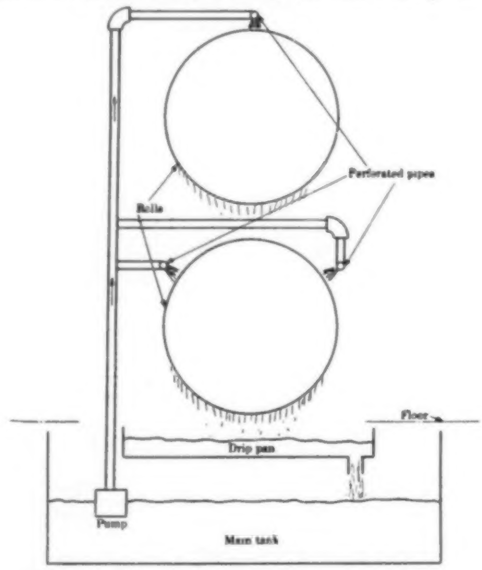


Fig. 4.—Schematic lay-out of the cooling system.

Methods employed at various plants for lubricating and cooling are described briefly in the following.

At one plant kerosene is used as the lubricant. Before starting the first pass the hot roller sprays each ingot with kerosene from a spray gun. Ingots are rolled one after another for about 25 to 30 minutes, when the passing is stopped, and the rolls are cooled with a water spray for about 15 minutes. The water is delivered from a perforated pipe above the upper roll ; the rolls are revolved during the cooling. Slabs are thus rolled during about 70% of the working time. Kerosene is a good lubricant in that it imparts a bright polish to the slabs. However, with the practice just described, the rolls tend to overheat and fire-crack.

(*Continued on page* 176.)

The Low-frequency Induction Furnace and Its Scope*

By A. G. Robiette, B.Sc.

Improvements in lining methods have made possible the melting and superheating of cast iron, the melting of high-copper alloys, nickel brasses, and cupra-nickel alloys.

THE subsequent development of the submerged-ring type induction furnace for the melting of other metals has hitherto stumbled on the limitations of the refractory material forming the secondary slot. For copper-zinc alloys containing copper up to 70% a clay-base refractory has been found eminently satisfactory, and if lead does not exceed about 3% there is no appreciable attack on the lining. An average life obtained from a lining of this type is 1,500,000 lb. of metal, while many have greatly exceeded this figure. There is a case on record where a lining lasted over six years before failure. From these figures it is evident that there is a great saving over crucible costs. A lining of this type is rammed in a plastic condition around a suitable wooden pattern, which is afterwards burnt out, and the lining well dried before starting-up. Recently, prefired and preformed blocks of refractory material containing the secondary slot have been found even more satisfactory for certain purposes. Such blocks require less skill in assembling than the ramming of a plastic lining, and are advantageous in cases where there are only a few furnace installations and where trained labour is not available.

Improvements in refractory materials have made possible the melting of cupro-nickel-zinc alloys—generally termed nickel silvers, but perhaps more correctly nickel brasses,—and a lining life of 2,000 heats can now be obtained.

The application of the Rohn patented fritting method which has been found so beneficial with coreless induction furnaces, has further extended the scope of the Ajax-Wyatt furnace. In this method a dry, refractory cement, containing a binding substance, is poured and lightly rammed around a metallic former, the latter being heated by induction to such a temperature that the cement sinters and forms a hard resistant lining. Cupro-nickel and phosphor bronze are now being melted in linings made after this process, and recently linings for phosphor bronze have lasted six months in continuous operation. The lining used in both the above instances was composed of pure quartzite with an admixture of suitable fritting material.

This method of melting holds out considerable promise ior the melting of pure copper, and a certain installation is at present producing copper-wire bars with considerable success. The most satisfactory lining yet discovered for this purpose has a corundum base, and the average life obtained is 600 heats.

Another interesting development is in connection with the superheating of cast iron. The effect of superheat and the addition of alloying elements to grey cast iron is now generally appreciated. Superheating by allowing of the complete solution of graphite enables a "super-cooling" effect to be obtained, due to the absence of graphite nuclei on which the graphite flakes grow. The graphite subsequently separates at a lower temperature in a very finely divided or nodular form, this giving increased tensile properties and a denser product. Fig. 5 shows the structure of a bar of grey iron superheated in the Ajax-Wyatt furnace.

(* *Continued from page 155, September issue.*)

The electric furnace is the ideal appliance for this operation, as it enables a rapid and controllable degree of superheat to be imparted, while at the same time alloying additions can be made and the composition adjusted as desired. Arc furnaces have for some time been in use for this purpose, but the submerged channel induction furnace offers further advantages of a lower power consumption and an intense stirring motion, which materially aids the rapid assimilation of the alloying additions. Its future lies probably in its use as a fore-hearth to a cupola. Such an arrangement is illustrated in Fig. 6.

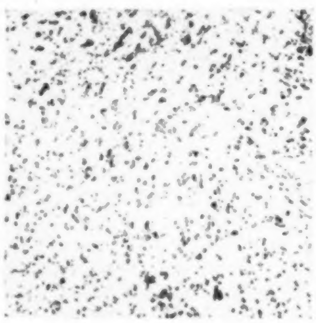


Fig. 5.—Structure of Gray Iron Superheated in an Ajax-Wyatt Furnace

M. Tama,† in a paper recently published, gives some interesting comparative analyses of cast irons superheated in an induction and an oil-fired fore-hearth. It was found that in an oil-fired fore-hearth the heating was only superficial, and with metal from a cupola at a temperature of 1,400° C. the metal tapped from the bottom of the fore-hearth was only 1,360° C., the cooling taking place during the transference to the fore-hearth. The power consumption for a superheat of 200° C. is approximately 60 units per ton, which is well below the very best arc-furnace practice, and compares favourably with fuel-fired fore-hearths.

Fig. 6.—Superheated Cupola Metal being tapped from a stationary furnace.

The lining which has been used is composed of fritted quartzite, and is formed by the Rohn method. The life of this lining in continuous operation is approximately

† American Foundrymen's Association, May, 1930.

one month, but improvements in refractory materials will probably increase this figure. The furnace shown in the illustration Fig. 6 is of the stationary type, the cupola metal being charged by means of runners, and the superheated metal is teemed through a side taphole.

Another interesting application is in the melting of zinc for the production of fine zinc sheet for photo-engraving work. This process has now superseded the old crucible method in the Atlantic Zinc Works at Brooklyn, and has effectively eliminated the imperfections previously experienced in the finished product. These take the form of elongated streaks on the finished plates, and were caused by the existence of pinholes on the original cast slabs. The improvement is attributed to the fine temperature control and the improved melting and mixing conditions. Besides improvement in quality, the melting cost was reduced—the power consumption being 115 units per ton,—and the zinc loss amounted to only one-quarter of 1%, while the lining after having produced two million pounds of metal appeared in perfect condition.

So far the use of the Ajax-Wyatt furnace has been mainly restricted in non-ferrous practice to the wrought-metal industry, but in America, where conditions are conducive to mass production, with a consequent tendency to standardisation of foundries to a certain class of work, it is finding an increasing application. In Europe, where the jobbing foundry is the rule rather than the exception, the progress of the induction furnace will naturally be slower in this direction. For foundry work the Ajax-Wyatt furnace had two main disadvantages : firstly, the limitations imposed by refractory materials narrowed its scope to the melting of certain copper-zinc alloys only ; and, secondly, it is inflexible to mixture changes. It was these objections which brought the indirect arc type of furnace into favour ; the best-known representatives of this type being the Detroit and Watson furnaces. The principle of heating, however, is entirely wrong from the point of view of the brass-melter. The metal is heated by intense radiation from an incandescent arc, and the rate of melting is governed by temperature gradient. To minimise zinc loss, which is considerable in this type of furnace, a rocking motion is given to the furnace to distribute the intense localised heat of the arc.

The arc furnace up to quite recently had a well-defined rôle to fulfil in non-ferrous melting practice. It was used for melting alloys exceeding 90% copper, and also in foundries working intermittently, or casting metals of widely differing composition. The induction furnace has since increased its range of utility by the improvements in refractory materials and methods of lining recorded above, so that the first objection has been removed. The disadvantage of inflexibility to mixture changes is more apparent than real, and only becomes serious when the composition is very frequently changed.

The Most Efficient Electric Furnace.

Perhaps the real predominating feature of the submerged channel induction furnace is the fact that it is by far the most efficient electric melting furnace yet conceived. The efficiency of the conversion of electricity to heat is extremely high, and approximates 90%. With regard to "operating efficiency"—or, in other words, the number of kilowatt-hours consumed per ton of metal melted—this depends upon working conditions, the chief factors being the number of hours worked, the duration of the pouring time, and the casting temperature. Under the most favourable conditions—*i.e.*, continuous working and short pouring time—yellow brass may be melted with a consumption of 200 units per ton. The electrical characteristics are also extremely favourable. The power factor varies between 80 and 90%, depending upon the size of the furnace and the frequency of the supply. The load factor is also high, since full load can be maintained throughout the heat, as all the resistance is contained in the secondary circuit, which is always kept full. During pouring, however, the load is reduced to 8 k.w. (for a 60-k.w. furnace) by means of a tapped auto-transformer, and this suffices to keep the metal in the secondary channel in the molten condition.

An idea of the present status of this type of induction furnace may be formed from the following statistics, which were recorded by H. W. Gillett in a paper read before the American Electrochemical Society on "Non-ferrous Electro-thermics in America." He states that 90% of wrought brass melted in 1926 was melted electrically, and that by the use of electricity 40,000 tons less fuel were consumed to generate the electricity than would have been used by direct fuel-fired furnaces. The savings in metal losses and crucibles alone amounted to £730,000. These figures have now been greatly exceeded, and in this country alone the output of brass from induction furnaces amounts to about 100,000 tons per annum. These figures are all the more remarkable when it is remembered that this revolution in the brass industry has taken place only in post-war times.

ALUMINIUM SHEET PRODUCTION

(*Continued from page* 174).

Transformer oil, light machine oil, cup grease, and other oils have been used as lubricants. At one plant kerosene is employed as the principal lubricant, but if the slabs tend to curl a little cup grease is rubbed on. At a German plant the ingot surface is rubbed with a chunk of bacon fastened to a stick, and a small amount of crude oil is thrown on the rolls from time to time. Lubricating oils may be conveniently applied to rolls and ingots by blowing as a mist from a spray gun, but they are often thrown on by hand dipper. Heavy greases are rubbed on the slabs.

At one plant lubrication and cooling are combined by spraying a mixture of 5% "Emulso" soluble oil with water on the rolls continuously. The "solution" is delivered to both rolls by means of perforated pipes, the supply being sufficient to keep both rolls covered with an appreciable layer. In another mill a more dilute oil-water mixture is fed continuously to the rolls, and a little kerosene is thrown on by dipper from time to time. When lubricating coolants are applied continually, the solution runs off into a tank beneath the mill and is pumped back.

Fig. 5 shows the schematic lay-out of the cooling system used in one mill. The tank for holding the bulk of the coolant is placed in the mill pit, and the solution is continually pumped to the perforated pipes arranged as shown. A catch-basin (drip-pan) is situated beneath the lower roll to receive the run-off, this flowing down to the tank through a sieved orifice. Two pipes may be arranged for the upper roll, if desired. As an alternative, solution from the main tank may be pumped to a small supply tank situated above the mill, delivery being made from this latter tank to the perforated pipes by gravity. Connection between the main supply pipe and the horizontal perforated pipes may be made by rubber hose. The arrangement for continuous cooling on a two-high reversible hot mill may be noted by reference to Fig. 2 in the August issue.

When a lubricating coolant, continuously applied, is used, the total available volume should be amply large to prevent excessive heating and evaporation. Thus, the capacity of the main tank should be about 2,500 to 5,000 gals. Consumption of soluble oil is very markedly decreased by substantial increase in the supply of coolant. The oil content of the solution should be renewed by suitable fresh additions, say every day or every other day, and the entire supply may be run to waste about once per month or once every other month.

In the next article of this series description is given of the various types of hot mills used in aluminium practice.

METALLURGIA

The British Journal of Metals.

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CONTENTS

METALLURGIA

THE BRITISH JOURNAL OF METALS.

THE MONETARY POLICY AND TRADE.

THE September returns of our foreign trade indicate all too clearly the effect of the world's crisis upon our exports, which during the first nine months of this year have fallen by nearly £149,000,000. Although the value of exports is substantially down the difference between exports and imports has risen to nearly £281,000,000 during the same period, compared to a difference of £269,000,000 and £276,000,000 during a similar period of 1929 and 1930 respectively. As is well known, this deficiency is more than covered by invisible exports in normal conditions, these latter exports embracing services like shipping and banking, and also including interest or profit on investments in other countries. While shipping is certainly in a depressed state, and has reduced our earning capacity, the chief cause of discrepancy in the trade balance is due to the fact that many investments have failed to pay dividends, and some debtor countries have been unable to pay interest. These adverse economic conditions have contributed to the abandonment of the gold standard despite the fact that the Budget has been balanced.

This position has been forced upon us by world conditions, which have caused intense competition for trade with a lowering of prices below an economic level. But the failure or inability of the United States and France to check the flow of gold towards them is also a contributory cause of the world crisis, and has indirectly assisted in the present monetary depreciation in this country. The events of the last few months have shown very forcibly that modern conditions involve a close international interdependence, and the need is becoming more and more essential for a closer and more active co-operation of the great powers and their banks. The world crisis has affected such problems as reparations, war debts, tariffs and monetary policy, and now they must be considered on a totally different basis and that without unnecessary delay.

It has been suggested that a solution to the present industrial crisis cannot be found by each nation fighting for what little trade is available, but by all working together to create a bigger demand. There is much wisdom in this suggestion, and if nations would act in such a spirit towards each other the world would be all the better for the co-ordination of the activities for international good in place of the mean competition for selfish national gain. Competition stimulates and is a factor to progress, but only when it is fair competition.

But "fair competition" is not necessarily a condition that can be obtained by the imposition of import tariffs. The gospel of Protection has been preached in Great Britain before and since the passing of the Corn Laws, and, although this journal has no politics, we would point out that, at the present time, industrial conditions are equally bad in Protectionist countries as in Free Trade Britain, and, further, that it was Free Trade Britain that carried the biggest burden of the allies during the war and that achieved victory. Many people in England still remember that, but there is no doubt there is a growing tendency towards trying the effect of import tariffs.

The situation in this country is not less critical than it was when the National Government was formed. It is imperative both to keep the Budget balanced and to secure a favourable balance of trade by whatever methods, whether related to currency, the expansion of imports or the restriction of imports, which may be found to be necessary and effective for the purpose. Already courageous steps have been taken to reduce expenditure and increase taxation to effect a balanced Budget, but the excess of imports over exports—including invisible items—must at all costs be eliminated. To this end the competitive power of the export trades must be increased, and if that involves sacrifices the country must realise that, as on the present occasion, the choice is between accepting those sacrifices or being overwhelmed by a general collapse. The people are, in an economic sense, in an experimental mood. Although unconvinced that tariffs would mean their salvation, they are more willing to make the experiment than they would have been a few years ago. A political student visiting this country to-day, after an absence of ten years, would immediately become conscious of the modified attitude of the people to tariff reform. But even this change of opinion does not make them achieve the tactics of some short-sighted and mean-spirited politicians when steadiness is the greatest need of the country. Mr. MacDonald was deserted by his colleagues of the Labour Party who had not the public spirit or moral courage to adopt measures of national economy that were essential, and his difficulties have been further increased by the present appeal to the electorate. Yet a great national effort was never more necessary nor the need of statesman-like handling of world problems more acute than to-day.

In the welter of political controversy raging as a result of the election it is natural that business is largely in a state of suspense, but there is no doubt that more inquiries are being received and the prospects generally are brighter than for a long time. A new sterling level is however needed, and it is questionable whether it will naturally stabilise until after the election.

It is too early to estimate the effect of the suspension of the gold standard on industry. It was generally assumed that it would operate somewhat similarly to a tariff, that the first effect would be to improve the prospect of export trade by reducing the price of products in foreign currency. Conversely, the price of foreign products would be increased in terms of sterling, thus tending to reduce imports. It will be some time before these reactions become manifest, and, while in some instances much business is being transacted, there is a general disposition to adopt a waiting attitude before taking steps to meet conditions as they arise.

It is generally believed that as soon as a new sterling level is stabilised industry will gradually assert itself, and a corresponding recovery will result in the Empire wherever our monetary policy holds sway. This would certainly effect considerable modification of the economic distress and political unrest that now tend to disturb Empire relations. There also appears to be a likelihood that other nations will follow our example and thus assist in bringing about the removal of the depressing effects of the gold position upon world trade. After all has been said, it is world recovery upon which we depend in effecting a correct trade balance, because such a recovery would not only improve our export trades but would stabilise our income from foreign investments, which would again set us on the road to prosperity.

THE MICROSCOPE AND THE INVESTIGATION OF ALLOYS.

THE industrial value of alloys depends largely upon their chemical composition and their physical constitution or structure; thus the initial aim of any systematic study of alloys must be to determine their chemical constitution and structure and subsequently to study the relation existing between these factors and their useful properties. No method is sufficient in itself to solve all the problems associated with the constitution of alloys, and therefore all methods which give useful information are used. The use of the microscope in conjunction with these methods is now recognised as indispensable. In conjunction with chemical and thermal methods, for instance, its use is essential for the preparation of equilibrium diagrams, and it also facilitates the systematic investigation of the physical properties of alloys and their characteristic changes under thermal and mechanical treatment. The microscope is also invaluable for determining the presence of impurities, mechanical defects, and for examining the effect of various stresses on structure.

Although the microscope was applied to metallurgical investigations as far back as 1722, it is only during comparatively recent years that rapid strides have been made in its application. The development of magnification from low-power instruments with magnitudes from 1 to 30 diameters to high-power instruments from 500 to 5,000 diameters, together with improved technique, is responsible for this rapid progress. The discovery of the way to make lenses from molten quartz enabled the construction of microscopes capable of being used with ultra-violet light. These ultra-microscopes for high-power work revealed the presence of particles beyond the scope of any other known means of microscopic vision. They take advantage of the increase in resolving power which accompanies a decrease in the wave-length of light employed.

A further development in microscopy was made in the use of polarised light. Investigators found that polarised light possessed many advantages in the examination of the surfaces of opaque substances, and this method has met with much success in the examination of ores. The use of the polarisation microscope has not yet, however, been adapted to any great extent to the investigation of metals and alloys. During the last twenty years Dr. Schwarz, of Munich, has been endeavouring to develop a method of application for polarised light in the investigation of metal slides, and we are able to publish the latest results of his work in this field. On pages 180-6 he gives some indication of the progress he has made in the investigation of non-ferrous alloys with polarised light, and he indicates future possibilities for the method.

It is well known that if a plate of crystal, cut parallel to the optic axis, is placed between Nicols at right-angles to one another, the polarised ray which passes through the first Nicol is capable of resolving into two, by double refraction. In consequence of this resolution, the waves can pierce the second Nicol to some extent; in so doing, they interfere with one another and produce the characteristic coloured rings. The application of this principle to metal plates or slides demonstrates the value of the polarisation microscope in revealing interesting facts.

Although this method is still in its initial stages, there is every likelihood that it will become of great value in research work and ultimately be recognised as an important laboratory method. Some further development will undoubtedly be made, but the article by Dr. Schwarz will serve a useful purpose in drawing attention to the more important and characteristic features arising from the investigation of metal slides with polarised light. It will assist in the discovery of new fields of employment and variations of methods.

Dr. Schwarz sent a large number of beautiful coloured slides, and we take this opportunity of thanking Dr. W. Rosenhain for his courtesy in assisting us in a selection for publication.

Forthcoming Meetings

THE IRON AND STEEL INSTITUTE.

SHEFFIELD

Oct. 20. Joint meeting with Sheffield Metallurgical Society. Papers to be discussed selected from—
"The Equilibrium of Certain Non-Metallic Systems," by J. H. Andrew, W. R. Maddocks, D. Howat, and E. A. Fowler.
"The Surface Hardening by Nitrogen of Special Aluminium-, Chromium-, Molybdenum Steels on a Production Basis," H. H. Cunningham, and J. S. Ashbury.
"The Effect of Surface Conditions Produced by Heat Treatment on the Fatigue Resistance of Spring Steels," by G. A. Hankins and M. L. Becker.
"The Solidification and Crystallisation of Steel Ingots," by B. Matuschka.

MANCHESTER.

Oct. 21. Joint meeting with Manchester Metallurgical Society. Papers to be discussed:—
"The Effect of Surface Conditions Produced by Heat Treatment on the Fatigue Resistance of Steel Springs," by G. A. Hankins and M. L. Becker.
"A Critical Study of the Origin of the Banded Structure of a Hot-Worked Hypo-Eutectoid Steel," by F. C. Thompson and R. Willows.

GLASGOW.

Oct. 30. Joint meeting with the West of Scotland Iron and Steel Institute. Papers to be discussed:—
"The Equilibrium of Certain Non-Metallic Systems. by J. H. Andrew, W. R. Maddocks, D. Howat, and E. A. Fowler.
"The Solidification and Crystallisation of Steel Ingots," by B. Matuschka.

Nov. 13. "Microphotography," by A. Macdougall.

THE INSTITUTION OF MECHANICAL ENGINEERS.

Oct. 23. General meeting. Presidential address by Lt.-Col. E. Kitson Clark, T.D., M.A.

Nov. 6. Thomas Hawksley Lecture to be delivered by Llewellyn B. Atkinson, on "The Mechanical Aspects of Electricity.

GRADUATES SECTION.

Oct. 26. "The Manufacture of Wire," by W. W. S. Robertson.

INSTITUTE OF METALS.

BIRMINGHAM SECTION.

Oct. 22. Inaugural Address, by Sir William Larke, K.B.E.
Oct. 31. Dinner and Dance at Queen's Hotel.
Nov. 12. Open discussion on "Mechanical Testing." (Opener: W. A. Benton.)

LONDON SECTION.

Nov. 12. "Some Recent Advances in Rolling Plant," by Dr. W. J. P. Rohn (meeting at Royal School of Mines).

NORTH-EAST COAST SECTION

Nov. 10. "Die-Casting," by A. H. Mundey.

SCOTTISH SECTION.

Nov. 9. "Experiences with Some Electric Furnaces for Melting Copper and Copper Alloys," by W. L. Govier.

SHEFFIELD SECTION.

Nov. 13. "Engineering Silver Solders," by E. A. Smith, A.R.S.M.

SWANSEA SECTION.

Nov. 10. "Some Causes of Unsoundness in Non-Ferrous Alloys," by Dr. D. Hanson.

THE INSTITUTE OF BRITISH FOUNDRYMEN.

LANCASHIRE BRANCH.

Nov. 7. "Production of Castings in a Modern Malleable Iron Foundry," by H. J. Beck. At College of Technology, Manchester.
Nov. 12. Ten Minutes' Papers, the first to be given by W. Barnes, at Burnley.

INSTITUTION OF ENGINEERS AND SHIPBUILDERS IN SCOTLAND.

Oct. 27. "Bonus Systems and Time Study," by Sam Mavor.
Nov. 3. "The Bottom Structure of Oil Tankers," by E. F. Spanner.

Correspondence on this in Dec. issue

The Micro-optical Investigation of Non-ferrous Alloys by Polarised Light

By Prof. Dr. M.v. Schwarz (Munich).

The first report on the employment of the polarisation microscope in the investigation of metals was given in a lecture by Dr. v. Schwarz at the Tenth General Meeting of the German Metallurgical Society on July 25th, 1928. As a result of further investigations, this scientific method has been developed, and new fields of employment have been discovered. Dr. v. Schwarz gives the results of his researches in the following article, which, together with the illustrations, indicates future possibilities for polarised light in simplifying investigations on metals.

THIRTY years ago J. Königsberger[1] showed that it is of an advantage to use polarised light for the examination of surfaces of opaque substances—*e.g.*, metals, ores, etc.,—and this method has, in fact, been much developed for examining ores (chalcography). In the case of metals, successful adoption of this method has not become known to any great extent, although reference has been made to the method in one or two articles[2] which have been published. It appears, however, that apart from L. C. Glaser[3] nobody seems to have entered on a close examination of the question. It should be mentioned that J. Weerts[4] has employed polarised light rays in the investigation of aluminium crystallisation.

Since 1912 I have been trying to develop the method that employs polarised light in the investigation of metal slides, but this has been somewhat difficult owing to the want of suitable apparatus. This deficiency has been removed by Dr. C. Reichert, Vienna, who at my instigation constructed a manageable polarisation opaque illuminator described in detail in the *Zeitschr. f. Metallkunde*, 17 (1925), S. 299. It is the purpose of this article to describe the advantages of polarised light in the investigation of metal slides, referring to practical cases, and especially to copper alloys.

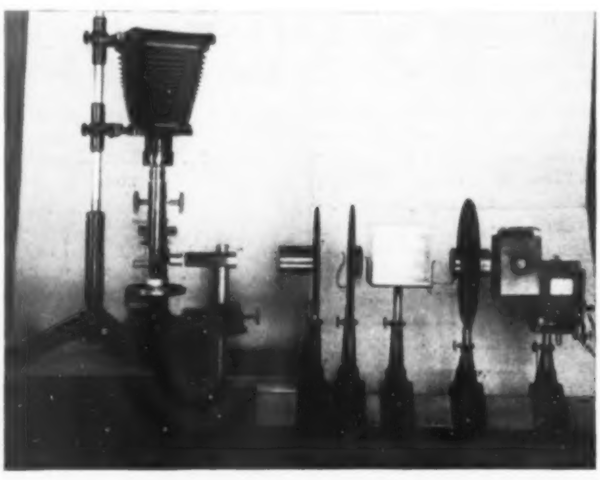


Fig. 1.—Reichert Polarisation Microscope with the Illuminating Device (arc-lamp, condenser, water chamber, diaphragm with light filter, illuminating lens), and the Camera.

The phenomena observed when polarised light is reflected by metal slides have hitherto not been satisfactorily elucidated, probably because various effects may be noticed which not only interfere with the polarisation, but also lead to some confusion. On the other hand, however, they may give valuable information with regard to the composition of metal slides.

For metallographic examination it is rather important to employ crossed Nicols, a qualitative method, in some cases, perhaps, together with retarding gypsum lamellæ of red colour, 1st and 2nd order, or with retarding wedges or quartz plates. According to L. C. Glaser, a quantitative method (photometrical method or with Savart plate) will be of some importance in the future, but in the present case reference will only be made to the simpler qualitative method.

[Nicol is the name given to a prism consisting of Iceland spar and used as a means of obtaining plane polarised light. If a ray of light falls on one of the faces of a rhombohedron of Iceland spar, part of the light passes straight through and part is refracted and travels and emerges along another line—*i.e.*, there are two refracted rays for one incident ray. In a Nicol prism one of the two rays is eliminated by internal reflection within the crystal, the prism being cut in two by a plane which is perpendicular to the principal plane of one face. The two surfaces are then polished and cemented together in their original position by means of a thin transparent film of Canadian balsam. This substance has refraction properties of a kind which so bend the rays coming to it through the face of the Iceland spar that one of the rays is totally reflected within the prism, and only emerges as plane polarised light. A Nicol prism may be used for producing polarised light, and for determining by analysis whether light is polarised or not, and the plane in which polarisation has taken place. It is named after William Nicol, of Edinburgh.—EDITOR.]

Perhaps the most important result received by the employment of polarised light is the fact that on the basis of the phenomena observed, isotrope (regularly crystallising) substances may be held apart from anisotrope substances (all other crystals), this being due to the fact that only slides of isotrope substances remain dark in any position when being examined under crossed Nicols, all others being of double refracting character. Rotation of the polarisation plane is the result, and owing to the employment of crossed Nicols, the various colours of polarisation will be found to clear up or darken four times alternately when turning

[1] J. Königsberger, *Zentralbl. f. Min. usw.*, 1901, S. 195/97, 1908, S. 565/73, 597/605, and 729/30; 1909, S. 245/50; 1910, S. 712/13; *Metallurgie*, 1909, S. 605/08.

[2] K. Endell and H. Hanemann, *Zeitschr. f. anorg. Chem.*, 83, 1913, S. 267/74; *Stahl u. Eisen* 33, 1913, S. 1644/46; L. C. Glaser, *Zeitschr. f. techn. Physik* 5, 1924, Nr. 6 S. 253/60: G. Sachs, *Z.f. Metallkunde*, 17, 1925, S. 299/300.

[3] L. C. Glaser and H. J. Seemann, "Zur Kenntnis der Phosphorbronzen auf Grund von optischen Untersuchungen im System Kupfer Phosphor-Zinn," *Zeitschr. f. Techn. Physik*, 7, 1926, Nr. 2 S. 90/92.

[4] J. Weerts, *Zeitschr. f. Techn. Physik*, 9, 1928, Heft 4 S. 126/136.

Fig. 2.—(m = 300). Highly Super-eutectic Alloy, Cuprous Oxide-copper, as seen with parallel Nicols. The cuprous oxide shows, just as with ordinary opaque illumination, a grey-blue colour.

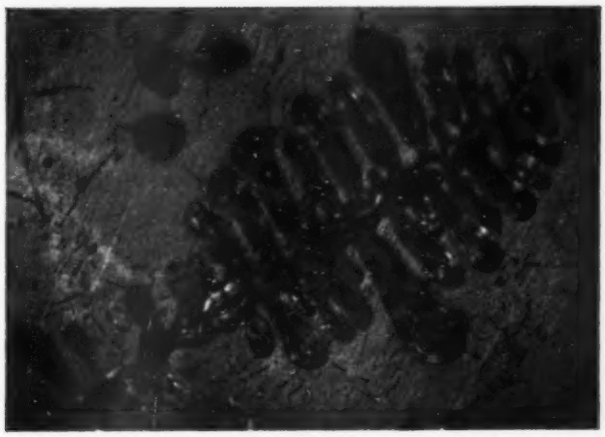


Fig. 3.—(m = 300). Same object as in Fig. 2, but with crossed Nicols, showing the cuprous oxide in its natural crimson colour.

the slide round 360°. The variations of the colours are only slight, as in the case of the pleochroic colours, observed with penetrating light and with one Nicol. In many cases there is only a slight change from grey-blue to brown. In other cases, however, especially with etched slides or when proving the presence of inner tension in metals, a quartz or mica plate may be inserted in the path of the rays, the position of the Nicol prisms being adjusted so as to make the sensitive colour "violet" appear. In this way clearly perceptible colour changes may be produced from the sensitive colour to red or blue, in the case of more intense double refraction to light yellow or green.

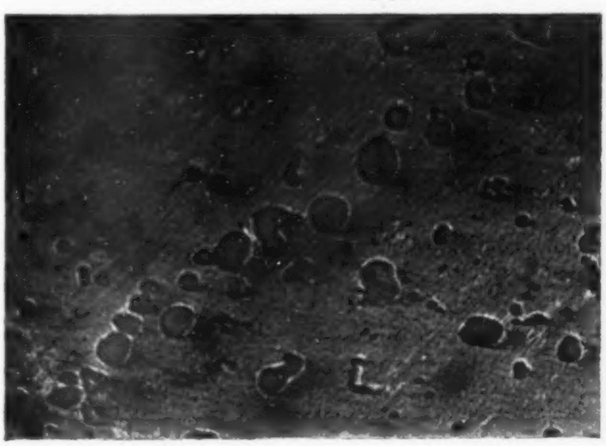
It may be incidentally said that the slides employed must be very carefully polished, and must be absolutely plain, free from pores or cracks, and should be fixed accurately at right-angles to the axis of the microscope, in order to avoid rather disagreeable perturbations when examining. It is also important that the objective lens of the microscope be free from inner tension, and does not contain any double refracting substances. When the linear polarised light coming from the polariser is reflected, rotation of the polarisation plane is noted in the case of anisotrope, opaque substances—*e.g.*, non-regular metals—mixed colours being then observed in the analyser fitted at right-angles to the polariser, contrary to the pure interference colours observed by polarisation in penetrating light. The phenomena of reflection are, therefore, somewhat different, and at the time it is not possible to infer on the intensity of double refraction on the base of these colours. The colours appearing are thus not only dependent on the intensity of double refraction, but also on the dispersion of the indices of refraction and on the index of absorption. The action on so-called compensators is, for this reason, somewhat different, and it is not the pure colours of interference that produce an effect.

The precedure to adopt when investigating by polarised light is somewhat different from normal practice and it is well to give a brief indication of the technique devised for this work by which the present investigations have been carried out.

Practically, it is well to proceed as follows: A carefully polished metal slide is, by means of a well-known press, or two pieces of plate-glass and an accurately turned ring, fixed plane-parallel on to a metal or glass plate with plasticine or some other lute. After the polarisation microscope has been properly adjusted, investigation may begin. (It is necessary to observe one or two details referred to in detailed directions given by Dr. C. Reichert.) For instance, the undulating direction of the polariser- or analyser-Nicol must be exactly at right-angles or parallel respectively to the plane of the totally reflecting prism or plane glass lamella. The direction of undulation must then lie accurately at right-angles between the tube or fitted analyser, in order to produce absolute darkness of the field of view with crossed Nicols (subsequently referred to as + Nicols). For subjective investigation it is quite sufficient to employ a small electric bulb placed with horizontal filament at some distance from the polariser. For photographic micro-exposures, however, it is absolutely necessary to employ an arc lamp, together with a large water chamber, in order to avoid dangerous heating of the Nicols.

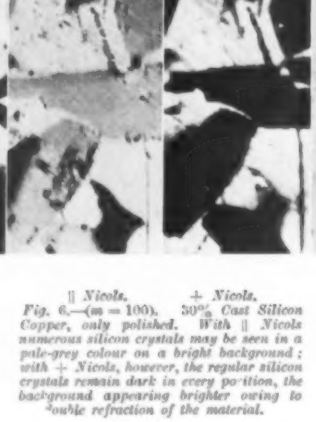
Details of the apparatus employed in the present case will be seen from Fig. 1. The slide is examined under crossed Nicols. If the field of view remains dark when turning the slide round 360° on the rotating stage, the substance is a non-polarising, amorphous, regularly crystallising substance, free from inner tension. Small hollow spaces, non-metallic contents (as, for instance, slag), further cracks and scratches left on badly polished slides, unfortunately produce bright spots owing to reflection. In the case of other substances—*e.g.*, cuprous oxide in copper alloys—the natural crimson colour is very nicely seen, because the linear polarised, superficially reflected light is absorbed by the analyser. Cuprous oxide, generally appearing in grey-blue colour when employing ordinary light, shows deep crimson colour on a dark background when examined under + Nicol, one of the most beautiful phenomena produced by the polarisation microscope. Cuprous sulphide, cuprous selenide, and cuprous telluride, appearing also in a blue-grey colour in ordinary light, remain practically the same even when examined under + Nicols. It is only in the case of larger quantities of

Fig. 4.—(m = 300). Contrary to Cuprous Oxide, a copper alloy containing 1% Selenium shows even with + Nicols grey-blue colour.



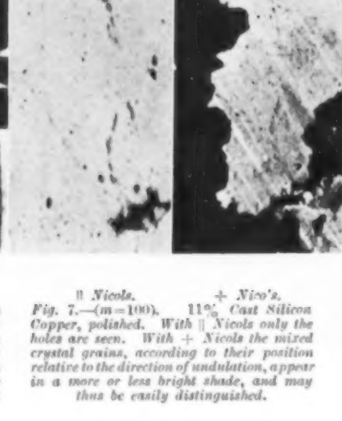
|| *Nicols.* + *Nicols.*

Fig. 5.—(m = 100). 20% Cast Silicon Copper, in which, after being polished, the silicon contained will be seen in a delicate grey. When examined under + Nicols this appears black, while crystals of the basic mass appear in more or less bright shades.



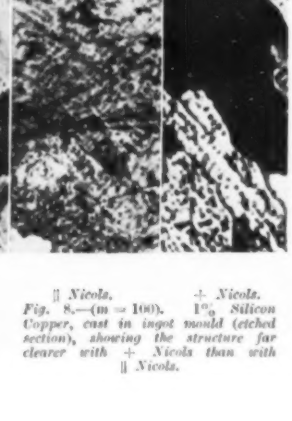
|| *Nicols.* + *Nicols.*

Fig. 6.—(m = 100). 30% Cast Silicon Copper, only polished. With || Nicols numerous silicon crystals may be seen in a pale-grey colour on a bright background; with + Nicols, however, the regular silicon crystals remain dark in every position, the background appearing brighter owing to double refraction of the material.



|| *Nicols.* + *Nico's.*

Fig. 7.—(m = 100). 11% Cast Silicon Copper, polished. With || Nicols only the holes are seen. With + Nicols the mixed crystal grains, according to their position relative to the direction of undulation, appear in a more or less bright shade, and may thus be easily distinguished.



|| *Nicols.* + *Nicols.*

Fig. 8.—(m = 100). 1% Silicon Copper, cast in ingot mould (etched section), showing the structure far clearer with + Nicols than with || Nicols.

cuprous sulphide that a slight double refraction is observed. (For quite a number of years I have always drawn attention to these facts in my lectures, and more information will be found in the article "Metallographische Prüfungen," *Messtechnik*, 1927, pages 10 and 11; and in the *Centralblatt der Hütten und Walzwerke*, 32, 1928, Heft 13, Seite 200/1). Figs. 2 and 3 show crystals of cuprous oxide in the eutectic base substance when placed between || (parallel) or + Nicol respectively. These colour effects can, of course, only be effectively reproduced if photographed in natural colours. In the ordinary black-and-white reproduction it is not possible to distinguish the contents of cuprous oxide from contents of cuprous sulphide and cuprous telluride. In Fig. 4 it will be noticed that cuprous selenide and cuprous telluride, which are only shown coloured once, remain grey-blue under || or + Nicols, and have nearly the same appearance as cuprous sulphide. Thus, any amount of cuprous oxide contained will be quickly and reliably detected with the help of the polarisation microscope.

In the meantime, Hauser has provided an opaque illuminator (dark field illuminator) with which it is possible also to examine the contents of cuprous oxide in natural colour. Subjective examination is rendered rather simple, but in the case of coloured micro-photographs and greater magnification the light intensity is hardly sufficient. The time of exposure required in one instance was 3½ hours, although only enlarged one-third as much as Figs. 2 and 3.

The coloured photographs reproduced in this article were produced with Agfa colour plates, using arc-light and filter No. 31. The time of exposure is about five to ten times as long as with ordinary orthochromatic plates—*i.e.*, about 1 to 30 secs. in the case of || Nicols, 5 to 3,000 secs. in the case of + Nicols, according to the brightness. It may be remarked here that it is not so very difficult to make such coloured photographs, and after a little practice good results will be obtained. It can reasonably be supposed that in future, and for purposes of metallography, this process will be widely employed, and will offer many advantages, as differences in colour are then far easier to discern than is possible with black-and-white reproductions, elements and details of structure being far more clear.

A typical polarisation phenomenon occurs in the case of a copper alloy containing about 11% of silicon; under || Nicols it shows apparently an evenly distributed bright basic mass with small groups of crystals arranged in rows (probably ferro-silicon). As soon as the Nicols are crossed, however, the basic mass is suddenly disintegrated into differently coloured mixed crystal grains. If the revolving stage is then turned 360° round, both the brown and violet colours of polarisation will be seen to appear twice alternately, this effect being produced by the mixed crystals. A vivid iridescence will also be observed, while some crystal parts remain dark, from which it may be assumed that these are ferro-silicon crystals—*i.e.*, regular. The results obtained indicate that the diagram presented by E. Rudolfi[7] is not quite correct, and a personal remark by W. Guertler, referring to recent investigations, seems to prove this too. In the examination of a material containing about 20% of silicon it was possible to discern larger crystals which remain dark under + Nicols. It is, unfortunately, not possible to demonstrate the beautiful change of colour when investigating slides with the help

[7] E. Rudolfi, *Zeitschr. f. anorg. Chem.*, 53, 1907, S. 223.

Fig. 9.—(m = 100). 1% Sand Cast Silicon Copper (etched transversal slide). It will be seen that although + Nicols give enough clearness with regard to the crystal grains, results may be greatly improved by further inserting gypsum lamella of 1st order red colour.

|| *Nicols.* + *Nicols.* + *Nicols and red 1st order.*

Fig. 14.—(m = 100). Coarse-grained Aluminium, deeply etched, showing the seeming polarising effect due to the etching grooves as seen under + Nicols. If a 1st order red gypsum lamelly is inserted, a fine colour effect is produced, making it possible clearly to discern the nature of the crystals present.

|| *Nicols.* + *Nicols.* + *Nicols and red 1st order.*

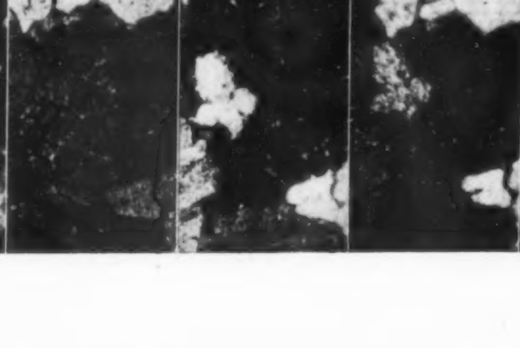
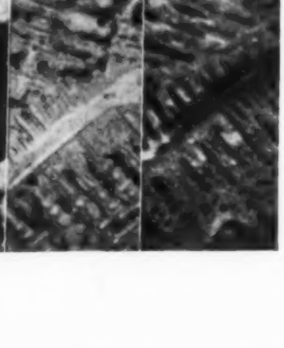
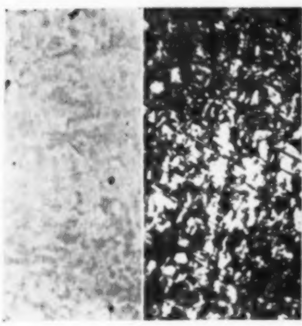


Fig. 15.—(m = 300). 5% Silicon Copper (cast in ingot mould), transverse slide, etched. Structure seen clearer with + Nicols than with ordinary light.

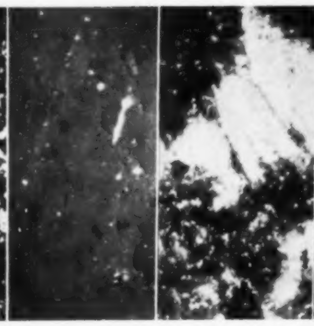
|| *Nicols.* + *Nicols.*





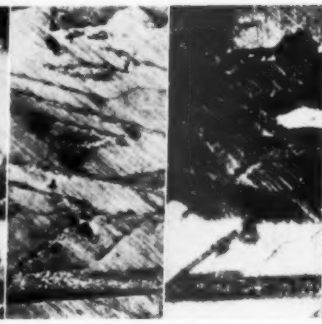
|| *Nicols.* + *Nicols.*

Fig. 16.—(m = 100). 50% Arsenic Copper, showing with || Nicols only slight signs of dendrites; + Nicols give a clearer view.



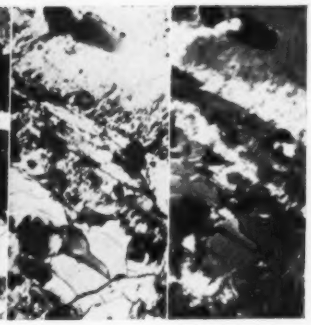
30% Manganic Copper, free of iron (left). Comp. 27% Manganese, 3% Iron, 70% copper (right).

Fig. 17.—(m = 300). Both slides polished only. Under + Nicols only the metal containing some amount of iron shows greater luminosity, probably due to manganic cementite.



|| *Nicols.* + *Nicols.*

Fig. 18.—(m = 100). 50% Cast Copper-aluminium, polished, showing under || Nicols large copper aluminide crystals and slight indication of the eutectic mixture. With + Nicols, however, bright spots of varying intensity may be discerned between the copper aluminide crystals.



|| *Nicols.* + *Nicols.*

Fig. 19.—(m = 100). 30% Iron Aluminium, polished, showing with || Nicols broken iron aluminide crystals in a coarse (very brittle) basic mass; with + Nicols, single iron aluminide crystals may be easily distinguished owing to different brightness.

of the polarisation microscope; it would be necessary first to produce a film with a film camera.

Figs. 5 and 6 show that even with a black-and-white reproduction it is possible to demonstrate the advantages offered by the investigation of metal slides under influence of polarised light, differences in brightness being fairly easily discernible. Fig. 5 shows a 20% silicon copper alloy which has been polished. Fig. 6 is a polished slide of a 30% silicon copper in which the rather large quantity of silicon crystals not subject to double refraction and (as seen in the right part) remaining dark under + Nicols are conspicuous.

But even in the case of copper alloys containing smaller quantities of silicon, disintegration of the basic mass into mixed crystals of different colour will be observed under + Nicols, as shown by Fig. 7, representing an alloy containing 11% of silicon. When photographing this and the following illustrations, one and the same part of the slide was focused in order to demonstrate clearly the advantages of the new method. The view as seen under || Nicols is practically similar to the view seen or photographed with an ordinary vertical or opaque illuminator.

By means of slight etching, the structure of silicon copper containing 1% of silicon (ingot mould cast), for instance, is hardly sufficiently cleared up, as will be seen in Fig. 8 (left part). If examined under + Nicols, however, the separate mixed crystal grains are easily discernible (Fig. 8, right part). Fig. 9 shows (left part) that after more intense etching the structure of the material—1% silicon copper (sand cast)—is more clearly distinguishable, but when seen under + Nicol, the picture seen is still more clear (middle picture, Fig. 9). Results may be still more improved by inserting a first-order red gypsum lamella between the Nicols, turning the latter until the violet colour appears. If the slide is now turned, the crystals contained in the material will appear in various colours. The right part of Fig. 9 proves that the phenomena mentioned cannot be demonstrated in a black-white reproduction as effectively as by the coloured pictures, Figs. 10, 11, and 12, showing the effect in different positions of the Nicols. Fig. 10 mainly shows the red colour of first order, as produced by the inserted gypsum lamella. In order to attain the greatest variation in the colour of mixed crystal grains, the polariser or the analyser Nicol is turned until the most sensitive colour, violet, appears. If the slide is then turned, maximal colour variation toward red or blue will be attained, as shown by Fig. 11. If the relative position of the Nicols is still further changed, the different colour shades become more or less livid, yellow and green shades then prevailing, as seen in Fig. 12.

A satisfactory explanation has not yet been given of the double refractory quality of silicon-copper mixed crystals. It may perhaps be assumed that the presence of the silicon in the copper is the cause of inner tension in the regular copper crystals, or an intermetallic silicon-copper composition is formed.

Referring to highly etched slides, also of regular, non-tension metals (*e.g.*, aluminium), vivid colour effects may often be observed with + Nicols and red of the first order, effects which may not be ascribed to polarisation, but which are perhaps more reflection phenomena connected with the etching grooves, taking up a different position among the mixed crystal grains irregularly distributed, but running parallel in the grain. G. Sachs has already

Fig. 20.—(m = 100). 14% Phosphorous Copper, polished, showing with || Nicols the copper-phosphide crystals surrounded by the eutectic mixture. Examination with + Nicols reveals gliding lines in the crystal grains and twin formation.

|| *Nicols.* + *Nicols.*

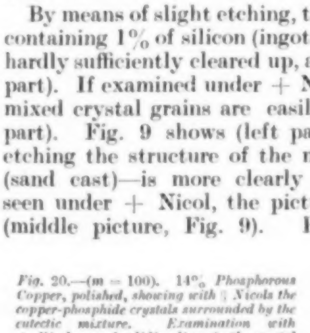


Fig. 22.—(m = 300). Phosphor-bronze (85% copper, 10% tin, 5% phosphorus). With || Nicols and only polished, the structure is only slightly indicated; the picture on the right (+ Nicols) shows clear details, and is far better than the view shown in the middle (the ordinary result with || Nicols).

|| *Nicols only polished.* || *Nicols etched.* + *Nicols only polished.*

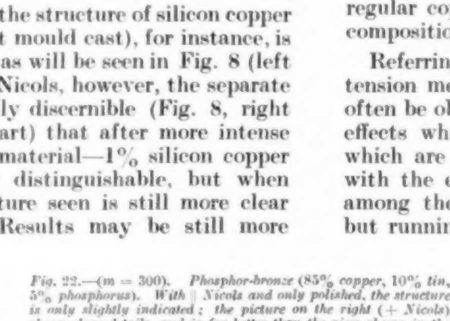


Fig. 25.—(m = 100). Two Crystals of Stannic Oxide in a slightly etched slide of bell bronze; left picture very unclear, hardly showing the stannic-oxide crystals; in the middle picture both crystals are clearly discernible, while in the picture on the right the slide has been turned round 90°, one of the crystals thus becoming invisible.

|| *Nicols.* + *Nicols.*

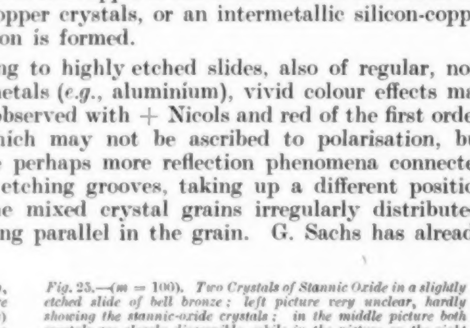


Fig. 10.—(m = 100). 1% Sandcast Silicon Copper (etched), + Nicols and red 1st order, showing slight difference in colour of the grains. (Etched with copper-ammonchloride-ammoniac.)

Fig. 11.—(m = 100). 1% Sand Cast Silicon Copper, strongly etched with copper-ammonchloride-ammoniac. With Nicols reciprocally turned 70° and red 1st order, the contrasts in the colour of the separate grains become more intense.

referred to this peculiar fact, which has also been repeatedly observed in ore slides. It may be of some use in determining the orientation of crystal grains in metal slides. For instance, in aluminium, copper, and iron, grains lying with one cube surface parallel to the grinding direction remain red. The others show varying colour according to their position when the slide is turned 360°, quite similar to the method of maximal luminosity employed and described by G. Tammann and H. H. Meyer[8]. In highly cold-rolled sheet metal, strip metal, or drawn wire, the homogeneous, parallel direction of the long-drawn metal crystal grains may be very clearly seen between crossed Nicols and the gypsum lamella ; this was effectively shown by aluminium plate rolled from 40 mm. thickness down to a thickness of 1 mm. In the case of such material no further preparation is necessary ; etching of a sample is quite sufficient. In black-white illustrations the removal of the colour is rather a disadvantage, but even so the long-drawn crystals are clearly visible.

Contrary to the case mentioned, a deeply etched aluminium slide of very coarse grain shows the grains lying in very different positions with regard to the slide surface, a fact easily seen from a difference in colour as shown by Fig. 13. Although the difference is not so clearly seen in black and white illustrations, due to absence of colours, the three-part illustrations, Fig. 14, will suffice to prove the advantage of investigation with the polarisation microscope.

In the case of slightly etched slides, also, the employment of the polarisation method will give better results than methods previously used, for the simple reason that contrasts are clearer and more sharply defined. Fig. 15 may be taken as an example, showing 6% silicon copper (ingot mould casting, section).

During the rather short time at my disposal only a few copper alloys could be examined, but it is probable that the cases mentioned here will suffice to draw attention to the great advantages of the method, and to the various phenomena to be observed. In the course of time no doubt further research work will reveal many other interesting facts.

The following illustrations will probably be of some practical value. Fig. 16 shows a 50% arsenical copper (only polished), the left side under ‖ Nicols showing only slight indications of structure, the right illustration, being the same part of the slide under + Nicols, showing the structure clearly, owing to the double refraction. When investigating manganic copper, examination with + Nicols makes it easy to determine whether the amount of iron-manganese carbide contained is high or not. On the left side of Fig. 17 a 30% manganic copper is shown (from the technical point of view free of iron) as seen under + Nicols in shape of a polished slide. There is no great amount of double refracting substance visible ; in the right illustration, however, showing also 30% manganic copper, but

[8] G. Tammann and H. H. Meyer, *Z. Met.*, 19, 1927, S. 82.

Fig. 21.—(m = 300). 14% Phosphor-Copper, polished, showing with + Nicols the various copper phosphide grains with twin lamellæ and gliding lines, as well as slight indications of the eutectic mixture.

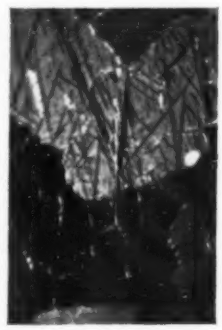


Fig. 26.—(m = 500). Stannic Oxide in a burnt bronze flux, containing cuprous oxide ; slide has only been polished. With + Nicols the stannic oxide is easily seen owing to the beautiful colours produced.

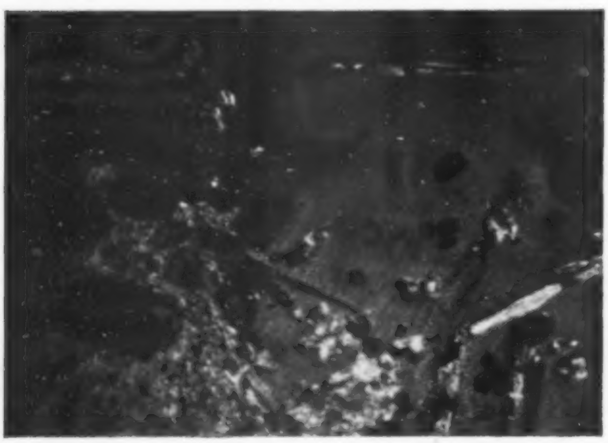
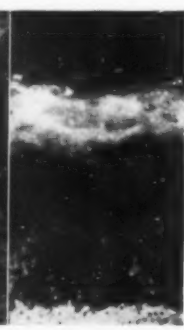


Fig. 23.—(m = 1,000). Phosphor-bronze (85% copper, 10% tin, 5% phosphorus), only polished, highly magnified, showing with + Nicols the tenary character of the eutectic mixture.

Fig. 24.—(m = 100). Transverse Slide of Bell Bronze buried in the Earth for 700 years ; photo. taken with an ordinary plate and with + Nicols.



Cuprous oxide = red.

Malachite (patina) = green.

Cuprous sulphide (probably) = brown.

Bronze = yellow tone

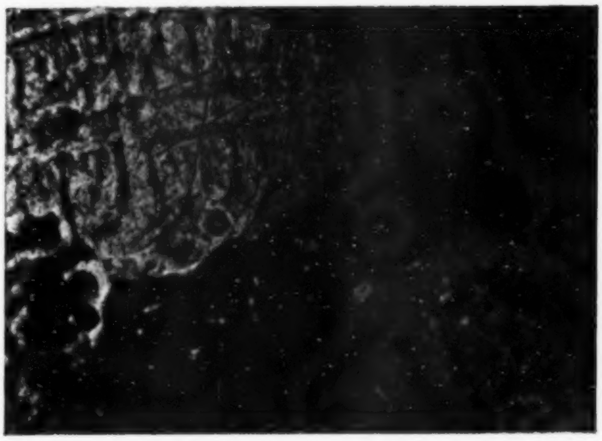


Fig. 12.—(m = 100). 1% Sand Cast Silicon Copper (etched). If the reciprocal position of the Nicols is turned back to 45° and with red 1st order, the contrasts in colour weaken.

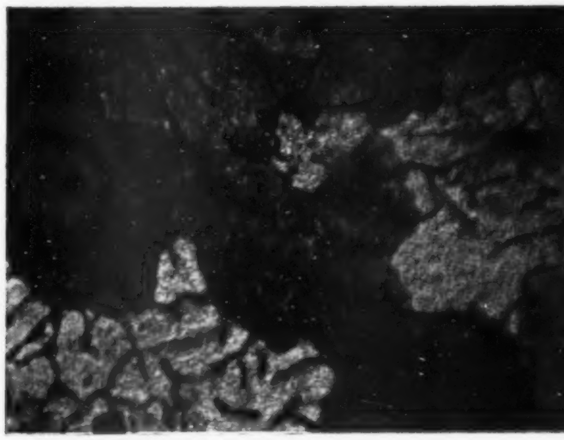


Fig. 13.—(m = 100). Strongly Etched Coarse-grained Aluminium (annealed or cast), showing with + Nicols and red 1st order clear contrasts in the colour of the crystals of different orientation.

with more iron (27% manganese, 3% iron), we are justified in supposing that the bright spots are iron-manganese carbide.

Copper aluminide has clear double refracting quality. Fig. 18 shows on the left side the slide under ‖ Nicols, on the right side the same part of the slide under + Nicols; the orientation of the copper aluminide crystals will be clearly seen if the luminosity is examined. The contrasts are not so clear in the case of iron aluminide, as proved by the right side of Fig. 19.

An alloy giving very good results with the polarisation method has been found in the shape of copper phosphide. Fig. 20 (left) shows the polished slide of a copper alloy containing 14% phosphorus under ‖ Nicols, where it is only possible to discern the copper phosphide crystals surrounded by the eutectic mixture; if the Nicols are now crossed the double refraction reproduces in the crystal grains gliding lines and twin lamellæ, as shown in Fig. 20 (right) and by Fig. 21, representing another copper slide.

L. C. Glaser has already referred to the fact that polarised light is of invaluable service in the investigation of phosphor-bronze. The three part-illustrations of Fig. 22 represent phosphor-bronze containing 85% of copper, 10% of tin, and 5% of phosphorus. On the left, as seen under ‖ Nicols, only a slight indication of the beautiful structure is discernible; the middle illustration shows the slightly etched slide as seen under ‖ Nicols, but only presenting the ordinary etching structure. It is difficult to see the tenary character of the eutectic mixture; the illustration on the right-hand side is a view of the same part of the slide as seen on the left illustration, but with + Nicols, giving a clear idea of the nature of the structure. If still more enlarged, the picture becomes still clearer (Fig. 23), and there is no difficulty in determining the nature of the eutectic mixture. In the case of phosphor-bronze it is of great advantage to employ a gypsum, or, better, a quartz lamella, because then the various elements of structure may, on account of their beautiful colours, be easily held apart.

An interesting case for which this method was employed with very fine results is worthy of mention here. The impulse to carry out experiments was provided by a fragment of a bell formerly belonging to the set of musical bells of an old church at Bethlehem, which came into my possession by mere chance. These bells had been presented in 1100 A.D. by crusaders, probably Normans. In the year 1200, shortly before the conquest of Bethlehem by the Saracens, the bells were buried in order to prevent their falling into the hands of the unbelievers, and about two and a half years ago they were accidentally discovered. Owing to the action of the earth on the metal during a period of about 700 years, a fairly thick layer of a kind of patina had been formed. On examination with a magnifying-glass this covering layer was found to consist of cuprous oxide (red copper ore) and green patina (malachite). A transverse slide examined with a polarisation microscope gave a fine result, as shown by Fig. 24. In the examination it was not only possible to discern details of structure easily, but the colours facilitated in determining the nature of the substances present.

The results obtained indicate that the polarisation microscope will prove to be of valuable assistance for the investigation of such patina covering. Referring again to the piece of bell bronze mentioned, it will be of some

Fig. 27. (m = 300). Crystals of Stannic Oxide in a 10% bronze. On the left the polished slide as seen with ‖ Nicols; on the right, view of slide taken with an ordinary plate and + Nicols.

‖ Nicols. *+ Nicols.*

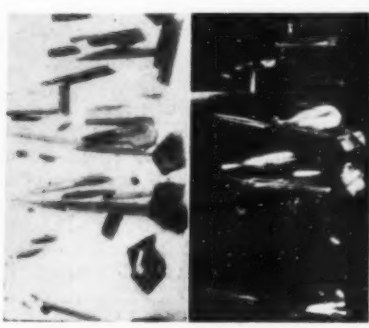


Fig. 28.—(m = 500). Crystals of Stannic Oxide contained in a 10% bronze (slide only polished) eradiate in different polarisation colours when seen under + Nicols. (See Fig. 38.)

Fig. 29.—(m = 750). The Polished Slide of a Burnt Bronze, showing with + Nicols the stannic acid in vivid polarisation colours.

interest to learn that when examining the slightly etched slide under + Nicols the structure not only became clearer, but it was also possible to detect two spots appearing in a different polarisation colour and in a brighter shade, representing another substance. It would hardly have been possible to detect these without or with ‖ Nicols, as in this case the contrasts are too slight (left illustration of Fig. 25). In Fig. 25 (middle), however, the more intense gleaming of these crystals as seen under + Nicols is shown. In spite of the fact that good, anti-halo plates were employed, a rather intense halo was produced round these crystals (recognised as being stannic oxide, SnO_2). When examining the prepared slide, the crystals disappear four times alternately when turning the slide round 360°. The right part of Fig. 25 shows the same part of the slide as the middle illustration, but turned 90°, one of the crystals being invisible.

In order to prove that these crystals are really stannic oxide crystals, various specimens of copper alloy were intentionally burnt for the purpose of producing a greater amount of stannic acid in the bronze. It was, however, discovered that the gas-oven at disposal was not sufficient to produce the heat necessary for oxidisation. Two other methods were found for the purpose mentioned. In the first case the tin was separately heated by an oxidising flame, the copper being subsequently added. In the second case, copper oxide as used for organic analysation was added to the molten bronze. It was noticed that in the vicinity of each copper oxide bacilliform crystal, stannic oxide was formed in the bronze, whereas the copper oxide itself was reduced. Oxidisation to cuprous oxide was only seen in the thin slag covering, as seen in the colour photograph Fig. 26. The polished slide of the investigated bronze showed (left) crimson cuprous oxide, and in the transitional zone numerous crystals of stannic oxide in the different colours of polarisation. In the interior of the bronze, and after the addition of copper oxide, stannic oxide crystals were detected round the copper oxide crystals, the copper oxide itself having been reduced.

Figs. 27, 28, and 29 show a different tin bronze containing rather large quantities of stannic acid. In the left part of Fig. 27 a polished slide is seen examined with ‖ Nicols; the same object is seen on the right side, but as seen with + Nicols. In the latter case it is, unfortunately, not possible to see the bright reflection of the stannic-oxide crystals, the photograph having been taken with an ordinary plate. If an oil-immersion objective lens is employed, the results are still better, as shown by Figs. 28 and 29. Fig. 28 is taken on an ordinary plate, Fig. 29 on a colour plate. (I would like to take the opportunity of referring to some first-class photographs taken in natural colours by L. C. Glaser, and contained in one of his works mentioned. The latter also contain photographs of tin alloys, which give fine results with the polarisation method.)

It is hoped that the few micro-exposures offered and the information given will suffice to draw the attention of professional colleagues to this new and valuable method of microscopic investigation and the many interesting facts it reveals. It may certainly be assumed that in the course of time new fields of employment and variations of the method will be discovered. I venture to hope that this article, with its illustrations, has been interesting enough to draw your attention to the more important and characteristic features pertaining to the investigation of metal slides with the help of polarised light. It may be safely assumed that in a short time this method will be one of the indispensable means of scientific research work, and will be of some importance for the laboratories of engineering works, as it affords great simplification. At present, it is still in its initial stage, but it will no doubt be further developed and eventually employed for determining inner tension in metals. Generally, it is hoped that this method of investigating metals with the help of polarised light will serve to facilitate progress in the metal industry.

Corrosion of Iron and Steel.

A recognised protective method.

Much increased attention is being concentrated upon the subject of corrosion, and especially the protection of machinery and iron and steel generally, a subject of vital importance, of course, in view of the fact that many millions of tons of steel are destroyed every year for this reason. The latest addition to the huge bibliography that has grown up on the subject is the "First Report on the Corrosion of Iron and Steel," presented at the recent annual meeting in London of the Iron and Steel Institute, being a contribution of the Joint Committee of the Iron and Steel Institute and the National Federation of Iron and Steel Manufacturers.

Essentially, as a preliminary to other reports, an attempt has been made to summarise the available knowledge and data concerning rust and corrosion, while there is also included a detailed digest of the replies received from a questionnaire sent out to producers and consumers of iron and steel, giving their experiences of the corrosion of ferrous products.

It is well known, of course, that the figures for the destruction of steel by rust and corrosion are of an astounding character, and many millions of tons of steel are lost every year from this cause alone. The report states, however, that a striking result of their investigations to date, and especially as regards the replies to the questionnaire, is that steel, if properly protected, will last for a very long time. That is, a large proportion of the enormous loss is caused by failure to adopt suitable methods for minimising or preventing rust and corrosion. In this connection one of the most valuable, especially for the severe conditions of sea air, is the use of red-lead paint, which, in addition to forming a strongly adherent protective film, highly resistant to such deleterious influences as oxygen, moisture, carbon dioxide, the sun's rays, salt, and stray electric currents, has a pronounced "inhibiting" action. In fact the experience of over a century past shows there is no real substitute for this special paint, which as regards iron and steel occupies the same position as white-lead paints for woodwork. Every description of steel structure can be protected in this way against rust and corrosion, including for example docks and harbours, lighthouses, ships, oil-storage tanks, pipe lines, bridges, railways, power stations gasholders, pit-head gear, and structural iron and steel in buildings of all kinds. Notable, for example, is the Blackpool Tower, 480 ft. high, protected on these lines, which is in perfect condition to-day after nearly 40 years.

Undoubtedly also red-lead paint is extremely valuable for painting iron and steel embedded in concrete. There is now used for the purpose special non-setting red lead, which ensures that the paint will keep on storage in containers and can therefore be supplied in bulk. Essentially red lead of this character, made by the oxidation of molten lead with air in two stages with very accurate control, contains not less than 94% Pb_3O_4 (Plumbic tetroxide) and 99½% total oxides of lead, with not over 6% lead monoxide (PbO). Under these conditions setting or hardening of the paint does not take place, and it is no longer necessary to make small amounts of paint at a time in order to obtain the benefits of red lead.

The Value of Low Total Carbon Cast Irons

By W. West.

Valuable experimental work has been carried out by the author, at the Farrington Steel Works of Leyland Motors, with the object of determining the most suitable composition of cast iron to withstand heavy service, particularly abrasion, that casts reasonably well. The results were given before a meeting of the Lancashire Section of the Institute of British Foundrymen on October 3rd, and, by the courtesy of the author, are published in this article.

When the foundryman speaks of the greyness or whiteness of his iron, he refers more particularly to the graphitic carbon content rather than the combined carbon, because the graphite is more apparent from the fracture than the carbide or metallic matrix, in which the combined carbon is contained, the sum of the contents of the two kinds of carbon being given as the total carbon content.

The graphitic carbon is of importance, not for itself alone, but because it serves as an approximate inverse index of the combined carbon content contained in the metallic matrix. In a given total carbon content the more graphitic carbon there is, the less is the content of combined carbon. It is also a necessity for the production of a soft, easily machined metal, and, further, it assists the foundry to obtain a cheap and readily cast metal, capable of being poured into intricately designed shapes, a quality which is improved by means of an increase of the total carbon.

In some cases, too, the generation of the graphite is useful to the foundry process, because, occurring as it does during and immediately after solidification, it causes a sudden expansion which produces castings more accurately to the shape of the pattern.

These benefits, however, are derived by the founding and machining processes only, but do not entirely contribute to the quality of the metal, as the greater the amount of free graphitic carbon present, so is the product weakened and embrittled. The source and measure of the valuable qualities, such as strength and solidity, arise from the content of combined carbon contained in the cast iron. In this respect, steel provides an enlightening comparison with the carbon content entirely in the combined condition, which gives increased strength to the metal without any weakening influence such as the presence of free graphite creates.

This gain is heavily paid for, however, as the lower carbon content implies a much less fusibility and a higher casting temperature, and the lack of any expansion of the metal, such as the presence of graphitic carbon, would provide during solidification, leads to greater shrinkage and contraction in solidifying and cooling. It is around this point of shrinkage that the experiments given in this paper have been carried out.

It is apparent, therefore, that if maximum strength is the chief quality desired of a cast iron, then the characteristics of it should embrace at least the following three factors: (1) The total carbon content, hence the graphitic carbon should be as small as is consistent with soundness and machinability of the metal. (2) The combined carbon content must be as high as possible within the limits of machinability. (3) The graphitic carbon, if separated in compact masses, will contribute very largely.

Two outstanding factors connected with the use of low total carbon cast irons thus become available—viz., increased strength and increased liquid shrinkage.

The first of these is a decided advantage, as it has been abundantly proved that tensile strengths hitherto unheard of have been produced. It may be of interest, therefore, at this early stage to recapitulate the theories which have been given in time past and provide a partial explanation of the benefit derived in this direction. Our present knowledge of the nature of alloys, whatever composition these may be, have been elucidated by a correct understanding of the behaviour of water solutions.

At normal temperatures the maximum solubility of salt in water is 23·6%. With increased temperatures, however, the point of saturation is increased. It is in fact recognised that for any temperature a definite weight of water dissolves a definite weight of salt. If a boiling and saturated solution of salt is allowed to cool, the salt will continuously separate out as crystals until at a temperature of $-22°$ C. the remaining liquid freezes. The liquid last to freeze contains 23·6% of salt, an amount which coincides with that which goes into solution at ordinary temperatures.

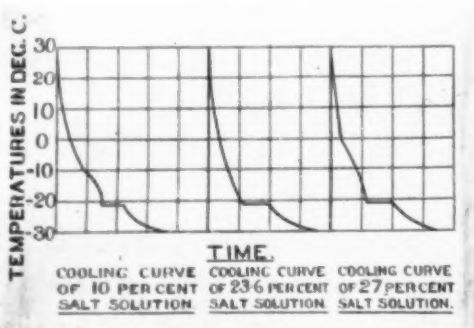


Fig. 1.—Three solutions have one common freezing temperature.

Pure water freezes to ice at 0° C., but an addition of salt in any quantity up to 23·6% lowers the freezing-point *pro rata* to the amount added, until at the maximum amount which will go into solution at ordinary temperatures—*i.e.*, 23 6%—the freezing-point is lowered to the furthermost point of $-22°$ C.

When the temperature of a solution with a saturation of under 23·6%, is lowered below 0° C., and cooling continued, ice crystals will separate and the remaining fluid portion becomes more and more concentrated until it contains 23·6% of salt, when it solidifies at $-22°$ C. A solution, therefore, containing 23.6% of salt solidifies or freezes as an unchanged whole without separation of ice or salt as the temperature of the solution is cooled to a temperature of $-22°$ C.

Fig. 1 shows that these three solutions have one common solidifying or freezing temperature—*i.e.*, $-22°$ C. To this point the dilute and concentrated solution behave similarly in that both separate the excess of one or other constituent during cooling. Thus, the concentrated solution separates solid crystals of salt and the dilute solution separates out solid water or ice until at the common freezing point each has reached the same concentration—*i.e.*, 23.6%.

It is, therefore, apparent that the final liquid portion has a composition which is independent of the original composition, and thus finally solidifies and melts at a constant temperature. This point in the case of metals is the eutectic composition, or the cryohydrate point in water solution.

If cast iron be considered for the moment in the light of a carbon-iron alloy, and assuming that the other constituents usually present exert no influence, it becomes evident that the proportion of carbon which will dissolve in iron at different temperatures is a factor of importance. Just as water at boiling point is capable of dissolving the maximum amount of salt which separates out on cooling, so iron at a high temperature will dissolve a large quantity of carbon which on cooling separates out in the form of plates of graphite.

Iron at its melting point dissolves 4·3% of carbon to form a carbide, the presence of manganese and chromium increases this solubility, while silicon, phosphorus, sulphur, and aluminium diminishes this power of solution of carbon in iron.

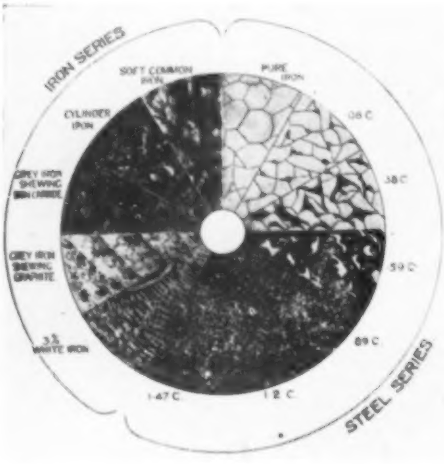


Fig. 2.—Effect of carbon on structure of iron.

Roughly speaking, carbon can exist in iron in two forms: That which separates out of solution as free graphite, and that which is retained in combination with iron in the form of combined carbon.

If pure and solid iron were treated in contact with solid carbon by heating to a temperature between 900° and 1,000° C., it would be found that the carbon had penetrated the iron, although neither is in the molten state. The carbon and iron had combined to form a carbide, and is an example of a solid solution of iron carbide in iron.

Consideration of Fig. 2 will give some idea as to the effect of iron on the structure by increasing the amounts of carbon. Increased carbon contents from 0·08% to 0·89% shows a gradual decrease of the white areas of pure iron (ferrite), and an increase of dark areas of iron carbide (pearlite) until at 0·89% carbon the whole mass is composed of iron carbide eutectoid—that is, a solid solution of iron carbide in iron. Further increase in the carbon contents produces a white network of glass-hard iron carbide (cementite) of a differing composition to iron carbide (pearlite), surrounding areas of iron carbide (pearlite). Thus, the amount of carbon can be increased until the iron will, when in the molten condition, take into liquid solution 4.3% carbon. Goerens, from his researches, herefore, concluded that carbon in molten iron is in solution as iron carbide, and that cast iron be considered strictly as a system of iron—iron carbide.

This molten solution of 4·3% carbon in iron, when allowed to cool down, solidifies at approximately 1,135° C., and is analogous to a 23·6% solution of salt in water, which has a constant solidification temperature of —22° C., and is, therefore, known as the carbon eutectic. If an iron-carbon alloy contains less than this eutectic amount, say, 3%, it will be found solidification takes place at a higher temperature, approximately 1,300° C., and that as the metal cools down separation of iron (ferrite) will take place until the temperature reaches 1,135° C., when the remaining liquid would have a eutectic composition of 4·3% carbon, and would solidify as a whole. If a molten cast iron does absorb more carbon than the eutectic composition of 4·3%, this is thrown out of solution, as the molten iron cools down towards the solidifying point of 1,135° C., in the form of graphite, and rises to the surface of the metal, and is generally known as "Kish."

Consideration has only been given to a pure iron-carbon alloy series, wherein 4·3% carbon in iron forms the eutectic composition, or, in other words, the alloy containing the lowest melting-point of the series. The addition of other elements modifies the carbon percentage at which the eutectic composition is formed. The presence of 1% silicon reduces the eutectic composition by approximately 0·3%, and each 1% of phosphorus has a similar influence. So that an ordinary alloy containing 2% silicon and 1% phosphorus will be of eutectic composition when the carbon content is approximately 3·4%.

Molten cast iron, as tapped from the cupola, therefore, during the process of cooling, first throws off, in the form of kish or primary graphite, any carbon it may hold in solution over and above that amount required to form the eutectic. If, on the other hand, the amount of carbon is below that of the eutectic composition, pure iron (ferrite) is thrown out of solution until the concentrated liquid has this eutectic composition. The eutectic then solidifies and splits up, depending upon the rate of cooling and the percentage of silicon present, into free secondary graphite and combined carbon; this separation begins at 900° C., and is complete at 700° C.

If molten iron is chilled suddenly, so that the carbide eutectic cannot dissociate into graphite and combined carbon, hard castings will result owing to a high percentage of the latter. On the other hand, slow cooling leads to more complete separation of the carbon as graphite, and hence softens the iron.

Low Total Carbon in Relation to Combined Carbon.

The rate of cooling and the composition of the iron are two main factors which exercise the greatest influence upon the quality of the iron. Among all the constituents of the composition the graphitic carbon heavily predominates.

The development of the combined carbon matrix has been largely fostered during the last few years, so as to obtain one composed largely of soft iron (ferrite) for ductility, or of pearlitic structure for strength.

Thus we have the introduction of low-carbon irons, and Jungbluth[1] indicates that all the irons giving tensile results of over 20 tons per square inch have less than 3% total carbon, with the exception of irons superheated in the electric furnace, or jolted when molten.

Norbury and Morgan[2] state that in relation to normal graphite-structure cast irons, the tensile strength increases as the total carbon content decreases, and as the distance below the eutectic composition increases. For normal graphite-pearlitic irons, the strength at the eutectic composition is about 10 tons per square inch, and increases up to 24 tons per sq. in. as the total carbon decreases to 3% and the silicon to 1·5%. Still higher strengths are obtainable with normal graphite irons containing about 2·4% total carbon and 2% silicon.

Low Total Carbon in Relation to the Silicon Content.

For a long time it has been recognised that the size and distribution of the graphitic carbon has a very deciding influence upon the tensile strength. Anderson and Bessmen,[3] give the results of their experiments, which show that as the total carbon is lowered with a constant content of silicon and other constituents, the tensile strength is increased considerably. In each set of experiments they show that the combined carbon increases

1 In a Review of High-quality Cast Iron. (British Cast Iron Research Association, *Bulletin* No. 22).
2 *Journal Iron and Steel Institute*, May, 1930.
3 Anderson and Bessemer, *A.F.A.*, Vol. 36, 1928.

and the graphitic carbon decreases as the total carbon content is lowered in relation to a constant silicon content. On the other hand, a high silicon content, as well as a high total carbon content, favour the rapidity of carbide decomposition, resulting in larger graphite flakes and lower tensile strength.

That silicon and carbon contents supplement each other in the production of cast iron exhibiting high strength figures, is effectively shown by Klingenstein.[4] Further examples of this relationship between these two constituents are seen in the Lanz and Thyssen Emmel processes. The former process operates with a total carbon of 3·25% and a low silicon content of 0·7 to 1·0%, and depends upon the preheating of the mould into which the metal is cast to retard the cooling to such an extent as to produce an all-pearlitic iron. The Thyssen Emmel process makes use of a lower total carbon, 2·4 to 2·8%, with a higher silicon content of 1·8 to 2·3%, and attains the same object without any such heating-up of the mould.

A low-silicon content, as in the Lanz process, retards the rate of carbide disintegration, which necessitates the prolongation of the setting period of the iron, by preheating the moulds to differing degrees of temperature, according to the thickness of the section. Where the total carbon content is reduced, as in the Emmel process, the iron carbide is in a much more stable condition, and therefore permits of the use of a higher silicon content which, when added in quantities suited to the rates of cooling under ordinary conditions in the foundry, results in an appreciable improvement in the physical properties of the resulting cast iron.

The influence of superheating cast iron and its relation to the size of the graphite flakes, has been developed by Piwowarsky. He found that by increasing the temperature of the molten bath to 1,500° C. the graphite content is reduced, the combined carbon increased, and the residual graphitic carbon which separates on cooling is in a much finer state of subdivision. These results from superheating are shown to give increased strength to the resulting cast iron.

Hanemann explains this phenomenon by the "Germ" theory, whereby the superheating destroys or takes into solution to a greater degree nuclei of graphite flakes, which under ordinary conditions of melting remain suspended in the liquid iron and provide the starting point for a coarse crystallisation of the graphite which separates from the dissociated iron carbide during the cooling period.

Relation between Low Total Carbon Content and Liquid Shrinkage.

Where high-strength figures is the main point, it is apparent that the preceding consideration of low total carbon in relation to the structure is of paramount importance. It is, however, possible to carry out the search too far at the expense of foundry economics.

There is a popular belief that shrinkage and contraction effects are due to silicon content, but experiments show that this is not so. In a search for high strength and all-pearlitic iron copable of the maximum resistance to wear in automobile cylinders, the total carbon contents of one day's run was purposely decreased from 3·3% to 2·9% in an attempt to effect a finer state of the graphitic carbon. Substantially, the silicon content and amounts of other constituents remained the same, and the temperature of casting approximated 1,350° C. This temperature cannot be considered as a superheat in any way, and so was not responsible for the unexpected result.

With every casting there occurred a well-defined depression at every juncture where a change of section occurred. Fracture of the castings through the declivities showed a very close-grained and sound section. Fig. 3, with declivities over bosses which have been purposely enlarged, illustrates the positions of these liquid shrinkages on a six-cylinder block, and in Fig. 4 on a small oil-pump body, these serving only as two types of many other castings in which the trouble occurred.

It is at once apparent from the appearance of the declivities and the soundness of the fractured sections that the trouble is not the same as the usual shrinkage cavities which are common within thick sections of metal, where the skin is perfectly flat, and the cavity is only revealed upon drilling or machining into the part.

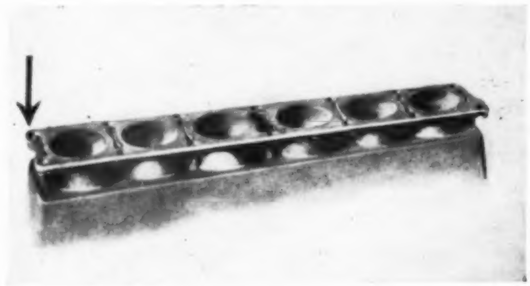


Fig. 3.—Declivities over bosses enlarged for illustration purposes.

Two queries arise as to the cause of the shrinkage and to its elimination :—

1. Is it a direct effect of the low total carbon content ?
2. Can it be eliminated by a reduction or increase in the silicon content or by superheating the molten iron ?

It is with the object of inquiring into these questions that the following experiments have been carried out, but as the work is being continued only a short summary of the results can be given at the present.

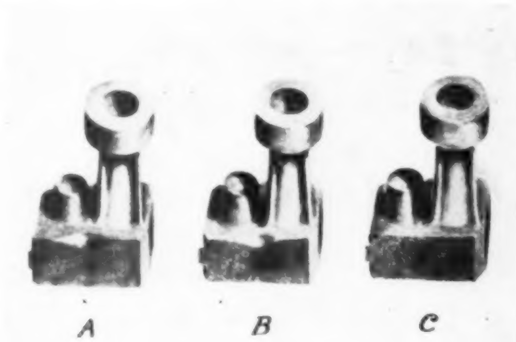


Fig. 4.—Small oil pump body.

The experimental work has been planned in the following order :—

Cupola Cast Irons.

Series A—Silicon content constant with variable total carbon.

Series B—Constant total carbon content with varying silicon content.

Crucible Cast and Superheated Irons.

Series C—To compare with Series A.

Series D—To compare with Series B.

Series E—Lower total carbon than previously used, with varying silicon contents.

Series A.—Represent a set of six separate casts throughout which the silicon content has been kept as near a constant as possible within the working of a small baby cupola, with an increasing total carbon content ranging from A1 at 2·75% to A5 at 3·7% in quarter percentages.

The "Baby" cupola through which the metal was melted is of the usual design, and capable of melting approximately 25 cwt. of cast iron per hour. For experimental purposes a type of casting—*i.e.*, an oil-pump

[4] Klingenstein, *Die Gaisserei*, February, 1926.

casting—was chosen as a standard sample in which to show any variation in the liquid shrinking effect with an alteration of the mixture.

While it was thought that the use of "Keep's" shrinkage test would give more accurate and technical information, it was decided that a more practical view should be taken, for time did not permit of an extension of the experiments on the one hand, and on the other, to practical minds, as those of foundrymen, it was deemed rather more satisfactory to express the results as visual observations than as graphs and figures.

The oil-pump casting is of ideal design through its grossly unequal sections to produce the maximum of shrinkage. Made in an oil-sand mould, conditions of casting from this point of view were standard, and the method of running down the stem through a cup runner having one small ingate was adopted all through.

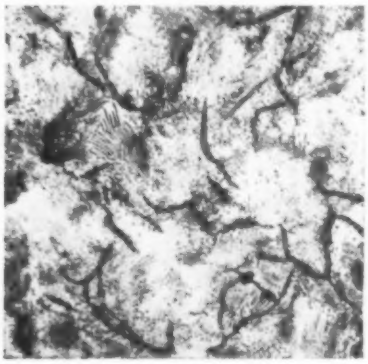
Tensile test-pieces, 1 in. × 1 in. × 9 in., and transverse 12 in. × 1 in. × 1 in. bars were cast in the upright position and made in oil-sand moulds. All tests were made in duplicate on 0·798 in. test bars, and no great variation in any of the two bars of each set was observed, except where blowholes occurred.

SERIES A.
TOTAL CARBON v. SILICON.
Temperature of Casting, 1,350° C.

—	Si, %.	T.C. %.	C.C., %.	Max. Stress in Tons.	Transverse 1 in. × 1 in. × 12 in. Cwts.	Type of Sink.
A1	1·86	2·75	0·94	21·4	32·8	Deep
A2	1·78	2·91	0·91	18·0	28·4	Deep
A3	1·78	3·24	0·67	16·0	Mis-run	Shallow
A4	1·60	3·51	0·63	14·8	28·0	Nil.
A5	1·90	3·70	0·63	13·0	33·0	Nil.

Manganese .. 0·80% approx.
Sulphur .... 0·06% ,,
Phosphorus . 0·40% ,,

Fracture.
A1 .... Solid, close grained.
A2 .... ,, ,,
A3 .... ,, ,,
A4 .... Open grain and spongy in section.
A5 .... Open grain and drawn in section.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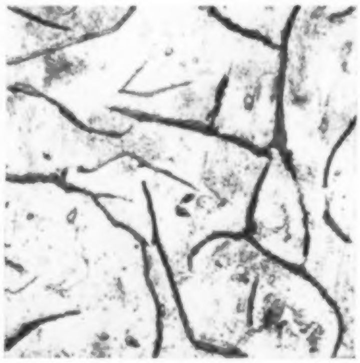

B

C

Fig. 5—Microphotographs of fractures shown in Fig. 4. Magnification × 200.

Experiments on Liquid Shrinking.

Types of Iron used in the Experiments.

SERIES A.

A1—Contained 50% pig iron and 50% steel, previously melted and cast before use.
A2—75% pig iron and 25% steel, the steel being added in the form of remelted iron.
A3—As No. 2.
A4—84% cold blast pig iron, 16% plate steel added to the cupola.
A5—100% pig iron.

SERIES B.

B1—75% pig iron, 25% steel, the steel being added in the form of synthetic pig iron.
B2—100% synthetic pig iron, 50% pig iron, 50% steel.
B3—As B2, correction of silicon by addition of ferro-silicon in furnace.
B4—As B3, by addition of ferro-silicon in furnace.
B5 to B9—As B2, by addition of ferro-silicon in furnace.

SERIES C.

C16—100% synthetic pig iron, 50% pig iron, 50% steel. Ferro-silicon added to furnace for silicon correction.
C17—70% pig iron, 30% steel. Steel added in form of synthetic pig iron.
C21—100% cold blast pig iron.
C18—80% pig iron, 20% steel. Steel added in form of synthetic pig iron.
C19—90% pig iron, 10% steel. Steel added in form of synthetic pig iron.
C20—100% pig iron.

SERIES D.

C25—70% pig iron, 30% steel. Steel added in form of synthetic pig iron-silicon correction in the furnace.
C26—Same as C25.
C27—Same as C25.

SERIES E.

C1—100% synthetic iron containing 50% steel addition.
C2—Same as C1, with ferro-silicon correction through the furnace.
C3, C14, C4, C8, C6, C7—Ditto.

Remarks on Series A.—The tensile strength of each cast decreases with increasing total carbon, which is what can be expected, but the transverse tests do not fall in the same ratio; this can only be accounted for by the usual fickleness of this test.

The liquid shrinkage took place very pronouncedly on the top of the heavy flat section of the casting in the first three casts, and when the total carbon had exceeded 3·24% a marked difference was observed, the phenomenon entirely disappearing with a content of 3·51%.

Experience has proved beyond doubt that the critical period for the occurrence of this liquid shrinkage commences when the total carbon falls to 3·24%, with an increasing marked degree as the content falls below this figure.

SERIES B.
SILICON v. TOTAL CARBON.
Casting Temperature, 1,350° C.

—	Si, %.	T.C., %.	C.C., %.	Max. Stress in Tons.	Transverse 1 in. × 1 in. × 12 in. Cwts.	Type of Sink.
B1	1·66	2·75	0·99	18·8	35·0	Deep
B2	1·86	2·75	0·94	20·0	32·8	,,
B3	1·96	2·75	0·75	19·2	31·0	,,
B4	2·12	2·71	0·92	Mis-run	Mis-run	,,
B5	2·32	2·75	0·85	17·6	Mis-run	,,
B6	2·84	2·60	0·85	16·6	33·0	,,
B7	2·88	2·53	0·73	17·0	32·0	,,
B8	3·12	2·56	0·90	18·24	33·2	,,
B9	3·62	2·55	0·61	18·6	35·0	Deep and localised drawn in centre.

Manganese .. 0·80% approx.
Sulphur .... 0·06% ,,
Phosphorus.. 0·40% ,,

Fracture.
B1—B9: Solid, close grained.

Remarks on Series B.—An increase in the silicon content with the total carbon in this series constant causes a similar decrease in the combined carbon as in Series A, where the silicon content is the constant and the total carbon the variable. The sink effect, however, remained unchanged throughout the series and clearly showed that an increase in silicon within the practical range of the series has no effect.

Turner[5] points out that a cast iron having a solidifying point of 1,150° C., on passing down through the cooling range, first expands and then contracts ; it then expands again and continues to contract. At the first expansion the coarse-grained graphite carbon begins to be separated, and continues to do so. At the next stage, somewhere about 900° C., a fair amount of fine-grained graphite is separated and continues to do so until at 700° C. this action is complete.

It was thought possible that by superheating the metal some alteration might be made in the order of the separation of graphite, and hence the shrinkage, expansion, and contraction, and that if this were so it might have some effect upon the liquid shrinkage under observation. Series C was, therefore, carried out at a casting temperature of 1,450° C., using the same mixtures and similar material to that used in Series A. The metal in this case was melted in a 200-lb. crucible pot in a forced-draught coke fire, by means of which a high temperature was obtained.

SERIES C.

TOTAL CARBON v. SILICON.

Crucible Melted and Cast at 1,450° C.

	T.C., %.	Si, %.	C.C., %.	Max. Stress in Tons.	Transverse 1 in. × 1 in. × 12 in. Cwts.	Type of Sink.
C16	2·67	2·5	0·52	21·4	35·0	Sunk and drawn
C17	3·16	1·92	0·45	17·1	34·0	Sunk
C21	3·30	2·00	0·86	16·0	28·0	Slightly sunk
C18	3·43	2·00	0·42	18·3	32·0	Nil.
C19	3·57	1·92	0·68	15·8	27·0	Nil.
C20	3·86	2·00	0·50	16·8	28·0	Nil.

Manganese .. 0·80% approx.
Sulphur .... 0·06% ,,
Phosphorus . 0·40% ,,

Fracture.

C16 ... Close grain, light grey
C17 ... ,, ,, ,, ,,
C21 ... ,, ,, ,, ,,
C18 ,, ,, dark ,,
C19 ... ,, ,, ,, ,,
C20 ... ,, ,, ,, ,,

Remarks on Series C.—The higher temperature of casting has caused the fracture of the higher total carbon specimens to be very much darker than the corresponding cupola-melted casts ; this phenomenon is quite marked. Microscopical examination of all the specimens will be made at a later date, and the results published.

Superheating has made a marked improvement in the transverse tests obtained in this series, as compared with those given in Series A. This can be explained by the finer distribution of graphitic carbon resulting from the superheating, as is evidenced in the darker colour of the fractures.

Liquid shrinking diminishes with a content of total carbon of 3·30%, which coincides with the results obtained in Series A ; there is not the coarsening of the grain in the centre of the sections, as the content of total carbon increases, as is characteristic of Series A.

Comparative figures were sought with Series B, where the total carbon was kept constant and the silicon percentage varied ; in this case the metal was melted in a crucible pot also, and the temperature raised to 1,450° C. A shortened series of casts can only be reported, as some of the lower-silicon-content experiments came out with erratic total carbon percentages, and were not reliable comparisons.

5 *Foundry Trades Journal*, Vol. 39, 644.

SERIES D.

SILICON v. TOTAL CARBON.

Crucible Melted and Cast at 1,450° C.

—	Si, %.	C.C., %.	T.C., %.	Max. Stress in Tons.	Transverse 1 in. × 1 in. × 12 in., Cwts.	Type of Sink.
C25	2·36	0·83	2·60	15·3	32·0	Deep
C26	3·06	0·79	2·60	15·8	29·0	Deep and drawn in section.
C27	4·30	0·70	2·50	14·9	28·0	Deep and drawn in section.

Manganese .. 0·80% approx.
Sulphur .... 0·06% ,,
Phosphorus . 0·40% ,,

Fracture.

C25—C27 : Close grain, light grey.

Remarks on Series D.—The tensile results from this series are very much lower than those obtained from cupola-melted casts of Series B, when comparing those of similar chemical composition. The transverse specimens suffer in the same way. The series is very limited in its scope, so that an indication only can be taken from the results, but as far as these have been taken, an increase in the silicon content has had little or no effect upon the liquid shrinkage under conditions of superheating.

It was quite by accident that the E series of casts was made, owing to a loss in the total carbon during crucible melting being greater than that anticipated. The results show a fixed total carbon lower than any of the previous series, with varying increases of silicon content.

The molten metal was in each case superheated to a temperature of 1,450° C., and the usual procedure followed.

SERIES E.

SILICON v. TOTAL CARBON.

Crucible melted and cast at 1,450° C.

—	Si, %.	C.C., %.	T.C., %.	Max. Stress in Tons.	Transverse 1 in. × 12 in. × 1 in., Cwts.	Type of Sink.
C1	1·86	1·32	2·15	—	38·0	Sunk and drawn
C2	2·16	1·06	1·90	21·2	38·5	,, ,,
C3	2·30	0·93	2·01	21·4	39·5	,, ,,
C14	3·04	0·73	1·99	16·8	35·0	,, ,,
C4	3·34	0·85	1·90	18·9	36·0	,, ,,
C8	4·30	0·80	1·91	17·8	34·0	,, ,,
C6	4·70	0·58	1·94	18·4	30·0	,, ,,
C7	5·42	0·41	1·94	16·4	25·0	,, ,,

Manganese .. 0·80% approx.
Sulphur .... 0·10% ,,
Phosphorus . 0·40% ,,

Fractures.

C1—C7 : Close grain and light grey.

Remarks on Series E.—Sinking in the thick sections occurred with this series, accompanied by severe tearing of the metal during solidification. This was particularly marked in the castings where the silicon content was higher than 3·34%. As might be expected, the tensile test and transverse results are exceptionally good throughout the series.

Conclusions.

The innumerable combinations which can be obtained from the number of constituents of cast iron give some idea of the complex nature of this alloy. The phase rule, however, shows that during the cooling of any one mixture only one substance can separate out at one time. Keep has shown in his experiments that in addition to two expansions which occur during the solidification of cast iron due to the separation of primary and secondary graphite, a third expansion occurs with phosphoric irons when the phosphide eutectic is formed.

It follows, therefore, that the coarser the graphite or higher the total carbon content, especially when accompanied by a corresponding silicon or phosphorus content,

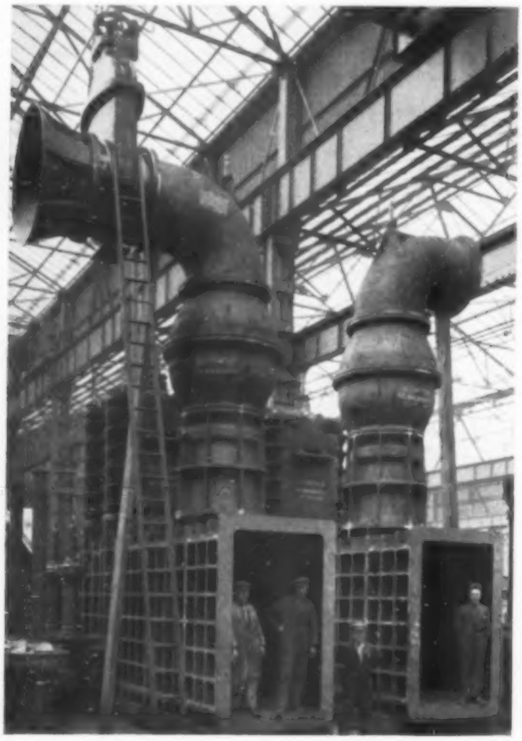
(*Continued at foot of next page.*)

THE PATJAL STORAGE DAM IN JAVA.

A Notable Installation of Large Tunnel Sluices and Valves.

AT the present time there is under construction in Java, for the Government of the Dutch East Indies, an important water-supply scheme known as the Patjal, involving the erection of an extensive dam possessing a number of interesting features, particularly in connection with the arrangement of the draw-off valves, because of the large amount of silt that will collect, due to the local conditions.

In this connection we are able to give some information, together with photographs, of the draw-off equipment that has been supplied by Messrs. Glenfield and Kennedy, Ltd., of Kilmarnock, and which has been tested exhaustively by inspectors of the Dutch Government, with results that have much exceeded their requirements and expectations, both during manufacture and after complete erection in the engineering shops at Kilmarnock.



Sluices and valves for large tunnel.

The complete contract in this connection included four tunnel sluices, 1·25 metres by 2·10 metres (4 ft. 1½ in. × 7 ft.), designed to withstand and operate under a head of water of 33 metres (108 ft.) above the sill, with no back pressure; two needle valves each 1·0 metre (3 ft. 3 in. inlet) with "Venturi" throat 0·914 metre (3 ft.) opening out to 1·0 metre (3 ft. 3 in.), and two double-flanged sluice valves, 1·0 metre (3 ft. 3 in.), with bellmouth inlet pieces and 4 in. by-pass valves and bends, operated through spur gearing, along with a large amount of accessory equipment, including connecting pipes, tunnel linings, operating headstocks, and ordinary supply pipes.

The two sets of valves—that is, one needle valve and one double-flanged sluice valve in each set—are to be housed near the bottom of a reinforced concrete valve tower 117 ft. high, situated in the storage reservoir, the tunnel linings and sluice bodies being completely built into the concrete, but having the sluice domes and needle and sluice valves left exposed within the tower. Control is effected by means of rods for each of the sluices and valves carried up inside the tower and operated by worm-geared headstocks situated at the top, while normal draw-off from the reservoir is through the two circular bellmouth entrances built into the tower walls, which are 18 ft. above the floor of the reservoir, discharging vertically downwards through a bed into the rectangular culverts.

The amount of water passing is regulated by the needle valves, for which the sluice valves, normally in the full-open position, act as guards for use in the event of dismantling of the needle valves. Also the invert level of the sluices is located approximately on the floor of the reservoir, their purpose being to act as scour control valves for eliminating accumulations of silt, these sluices, as indicated being grouped in pairs, of which the down-stream unit acts as the normal operating sluice, with the up-stream unit as the guard. For this purpose the doors are of special design, being constructed of solid armour plate with perfectly smooth sides, to allow of easy passage through the silt, provided also with large section bronze seats, recessed and pinned in position. Also, the operating rods for these tunnel-sluice doors are of forged bronze, provided with coned collars to allow repacking the glands under pressure, the whole arrangement of the sluices and their operating headstocks being rigidly connected by mild steel tie-rods extending the full height of the valve tower.

The needle valves are the normal standard "Glenfield" design, with easily renewable seats and all bearings and working surfaces lined with gunmetal, while special precautions have been taken to avoid the effects of cavitation, the discharge sides of the valves being well ventilated through 6 in. diameter steel tubing extending to within 5 ft. of the top of the valve tower.

The headstocks also follow the firm's standard practice, having totally enclosed machine-cut worm-gearing working in an oil-bath, while in this connection the sluices have also an auxiliary set of high-power spur-gearing for the initial opening of the valves, the whole equipment constituting a fine example of modern hydraulic engineering

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The Value of Low Total Carbon Cast Irons

(Continued from previous page.)

the greater the expansion which will occur during solidification of the metal. On the other hand, the lower the total carbon content, so is the range of solidification reduced, owing to the higher point of temperature at which it occurs.

Osann[5] states that piping or sinking does not occur if the alloy is of eutectic composition. Where a low total carbon content of under 3% is employed, an increase in the silicon content, he suggests, will bring the iron to a state of eutectic, and one may expect therefrom little or no piping. The results, however, from the foregoing experiments, where the total carbon is kept constant and the silicon successively increased, does not bear out his assumption.

In the face of the results obtained by these experiments, it would appear that liquid shrinkage is only prevented by having the requisite amount of total carbon present to counteract it by its own expansion during solidification. The alternative is to make provision on the casting for risers of sufficient capacity to feed over sections where such liquid shrinkage is likely to occur.

The use of low total carbon irons to the foundryman is, therefore, seriously discountenanced by the difficulties encountered in foundry practice. Where high-test irons are a necessity, then the advantages gained outweigh other foundry disadvantages.

It may be, however, that the low total carbon cast irons will provide some valuable assistance to the increase of resistance to wear in automobile cylinders, and it is for this line of investigation that the above experiments primarily have been made.

Iron and Steel Institute

The Autumn Meeting at Swansea.

THE autumn meeting of the Iron and Steel Institute, held at Swansea, from September 29 to October 2, under the presidency of Col. Sir W. Charles Wright, proved to be comparable in every way with the usual high standard of these meetings. The South Wales Siemens Steel Association, representing local industries, were the hosts. The programme of technical meetings, visits to works, and social functions arranged by the local Committee were all that could be desired, and reflected great credit upon the organisers. So many works visits were available to members that selection was a real difficulty; amongst those visited during the course of the meeting being the Port Talbot and Margam Works of the British Iron and Steel Co., Ltd.; the South Wales Tin-plate Works, Llanelly; the King's Dock Tin-plate Works, Swansea; the National Oil Refineries of the Anglo-Persian Oil Co., Ltd., of Llandarcy; the Courtybella Works of the Whitehead Iron and Steel Co., Ltd., at Newport; the Swansea Vale Spelter Works of the National Smelting Co., Ltd.; and the works of Richard Nevill and Co., Ltd., of Llanelly.

Following a civic welcome on the first morning of the meeting a technical session was held for the consideration of a number of papers, and further meetings on subsequent mornings were allocated for a similar purpose. In all thirteen papers were presented, but in view of the limited time some were taken as read and submitted for written discussion. Considerable interest was displayed in the majority of the subjects chosen, but it is only possible here to refer to them somewhat briefly.

The Constitution of the Iron-tin Alloys.

There is an increasing need for accurate information concerning the formulæ, the chief characteristics and range of stability of all intermetallic compounds which can exist in binary systems of alloys, before a comprehensive conception of the nature of intermetallic combination can be adequately considered. With the object of obtaining reliable data relating to the constitution of the iron-tin alloys, Messrs. C. A. Edwards and A. Preece have carried out an investigation, the results of which are given in a paper. The authors briefly review previous work on the subject, and indicate various uncertainties associated with former investigations. The present research was undertaken primarily to throw more light on these uncertainties and depict them and other changes in a complete equilibrium diagram. This proved to be a greater problem than was anticipated, as many unexpected difficulties were encountered. In nearly all cases, however, these were overcome, and some inaccuracies in Wever and Reinecken's diagram were revealed.

Briefly, the results of this investigation give the iron-tin equilibrium diagram in which three compounds are shown to exist: (*a*) Fe_2Sn—which is stable between 760° C. and 900° C., but can react with tin at 800° C. to produce the compound FeSn; (*b*) FeSn—which is stable at all temperatures below 800° C., but reacts with tin below 496° C. to produce the compound $FeSn_2$; (*c*) $FeSn_2$—which exists below 496° C., and when heated above that temperature breaks down into FeSn plus a tin-rich liquid.

The authors prepared a sample of $FeSn_2$ in a very pure state, and found that the thermal transformations at 760° C. and 800° C., which Wever and Reinecken attributed to polymorphic changes occurring in $FeSn_2$, are shown to be in no way connected with $FeSn_2$, but are due respectively to the decomposition and formation of the compounds Fe_2Sn and FeSn.

No evidence could be obtained of the existence of Fe_3Sn which Wever and Reinecken show in their diagram. The evidence of the present work goes to demonstrate the non-existence of this compound. Further, the diagram given in this paper shows the existence of a range of limited miscibility, and in this respect agrees with that of Isaac and Tammann, and in this respect differs from Wever and Reinecken's diagram, which shows no limited miscibility range.

The investigation indicated that the solubility of tin in solid iron increases with increasing temperature up to 760° C., and then becomes less as the temperature is further raised to the melting-point of iron.

The Diffusion of Tin into Iron.

The early work on the iron-tin alloy consisted almost entirely of the identification of the various compounds of the two elements. Of these compounds only Fe_3Sn and $FeSn_2$ are now recognised in the equilibrium diagram of the iron-tin system. A recent and complete diagram by Wever and Reinecken recognises the compound Fe_3Sn as existing above 890° C. in a certain range, and the compound $FeSn_2$ as existing from 12 to 99.99% of tin by weight. The work by Messrs. C. O. Bannister and W. D. Jones, which is contained in a paper presented, deals with the formation of columnar crystals as well as the diffusion of tin into iron.

For this work cylindrical containers were prepared of Armco iron, each having a cavity into which high-quality tin was poured, and a bolt subsequently screwed about half-way down each cavity. After heating the prepared cylinders and cooling down they were cut for investigation. It was found possible to separate the specimens into three main classes, according to whether they had been heated below 900° C., between 900° C. and approximately 1,100° C., or above 1,100° C. In the first of the series no evidence of diffusion of tin into iron was found. In the second class, evidence was found that diffusion commences as soon as the cylinder reaches the necessary temperature, and before the tin is saturated with iron. This evidence was found by heating for ten minutes only at 1,000° C. On examination, the commencement of columnar growth was found, and microscopical examination showed that the tin contained only a few dendrites of tin-iron compound. Heating to 1,150° C. for 5 hours showed that the band of columnar crystals is still formed when the tin diffuses into the iron.

The authors briefly review previous work on columnar growth, and after a consideration of the materials employed by Grube and Kelley, they are led to the observation that aluminium, tin, chromium, tungsten, and molybdenum have the one characteristic in common, that of inhibiting the γ solid solution when a certain small percentage concentration of the solute is reached, as they show in the case of tin. Such a fact forms a basis for the explanation which the authors discuss. Further experimental work on the diffusion of tin into iron is given in this paper, and the authors discuss quantitative work on diffusion.

The Effect of Molybdenum on Carbon Steels.

Steels containing 0·30 to 0·35% of carbon, and 1 to 1·5% of manganese, have found increasing use in recent years, particularly in America, because of the superiority of their mechanical properties over those of carbon steels, especially in the heat-treated condition. These steels, however, do not harden deeply, and they tend to exhibit temper brittleness. Mr. G. Burns has carried out some investigations on some medium carbon steels containing

from 1 to 2·5% of manganese with the object of determining the effect of various percentages of molybdenum on their mechanical properties. The chemical analyses of the steels used are shown in Table I. Critical thermal ranges were determined, which indicate that the addition of molybdenum raises the Ac_1 point, but appears to have little effect on the end of Ac_3. On cooling, Ar_3 is depressed slightly and Ar_1 is considerably lowered, particularly in the steel containing 0·3% of molybdenum. Since the end of Ac_3 is not affected by the addition of molybdenum up to 0·3%, and the raising of Ac_1 is not very great, no alteration of heat-treatment temperatures is necessary when molybdenum is present.

TABLE I.

R.D. Mark.	Carbon, %.	Silicon, %.	Manganese, %.	Sulphur, %.	Phosphorus, %.	Molybdenum, %.
KEH	0.29	0.10	1.32	0.030	0.030	Nil
KEJ	0.35	0.11	1.24	0.025	0.025	0.22
KEK	0.32	0.11	1.22	0.015	0.020	0.32
CDO	0.36	0.09	2.24	0.027	0.025	Nil
DWW	0.30	0.15	2.30	0.030	0.025	0.52

In the steels containing 1·3% of manganese, as normalised, tests show that the addition of molybdenum up to 0·3% produces little improvement in the mechanical properties which could not be obtained equally well by an increase of the manganese, or manganese and carbon content. It has, however, a marked beneficial effect on the steel in the hardened and tempered condition.

Further, the author has found that the addition of 0·15 to 0·25% of molybdenum reduces the tendency to temper-brittleness, and causes more uniform hardening throughout the thickness of a section; while in the steels containing 2·3% of manganese, the addition of 0·5% of molybdenum almost eliminates the susceptibility to temper-brittleness, and gives mechanical properties approximating to those of nickel-chromium-molybdenum steels in the oil-hardened and tempered condition.

The Influence of Silicon on Nickel Steel.

The properties of nickel steels containing 4% of nickel, 0·4% of carbon, 0·3 to 0·8% of manganese, and 0·05 to 0·87% of silicon have been examined by Mr. R. Harrison, with special reference to the effect of the silicon. The investigation dealt with nickel steels for constructional purposes, in which it is customary to limit the amount of silicon to 0·3%. The object was to determine the effect on nickel steel of silicon up to about 1%, and if the results were of sufficient promise, to extend the work to steels of higher silicon content. Since the work completed revealed no probable advantage to be expected from the increased silicon control, the second part of the investigation was considered unnecessary.

As a result of the investigation, the author concludes that silicon raises the critical points, both on heating and cooling, the rise in the A_1 point of a 4% nickel steel being similar to that observed in carbon steel. The effect of silicon on 4% nickel steel, whether in the forged, rolled, or normalised condition, is a hardening effect. It increases the elastic limit, yield-point, and tensile strength, but reduces the elongation, reduction of area and notched-bar impact figure. For use as plates in the rolled or normalised condition, irregularity of properties due to partial air-hardening must be guarded against by keeping the silicon, as well as the manganese, below 0·5%. A similar hardening effect due to silicon is evident in steels which have received the same hardening and tempering treatment; but in small sections, hardened and tempered to give a stated hardness, the silicon has very little effect on the properties.

As the size of the section is increased, mass effect begins to show first in steels lowest in silicon. When the manganese is insufficient to ensure full hardening, the effect of a slight increase in manganese is greater than that of a considerable addition of silicon. When the manganese is already at a high figure, an increase of silicon maintains a hardened condition in somewhat larger sections.

The usual limit for silicon is 0·3%. Provided that homogeneous steels free from laminations are secured, there is no objection, from the point of view of mechanical properties, to the use of a considerably higher silicon content, except in rolled nickel-steel plate, in which it should not exceed 0·5%. On the other hand, no advantage is gained by abnormally high silicon. The steels investigated contained not more than 0·87% of silicon, but they gave no indication that any specially good mechanical properties are likely to be obtained by increasing the silicon to 1 or 2%.

Mottled Tinplates.

The occurrence of dull areas on tinplates, known as mottle, has been investigated by Mr. J. C. Jones. A disconcerting feature of this problem is the apparently haphazard way in which a pot suddenly begins to make mottled plates, and as suddenly, and for no apparent reason, reverts to the production of perfectly normal plates. Experiments indicated that when the tinning-pot conditions are favourable to the manufacture of mottled plates, even the purest iron obtainable in sufficient quantity for large-scale experiments develops the peculiar mottled structure in some measure.

The two chief factors upon which the formation of mottle depends are the steel base and the tinning-pot conditions, and experiments have shown that different types of steel tinned under identical conditions vary in the degree to which they are prone to exhibit these markings. The substitution of some other salts for the zinc chloride commonly used as a flux, has been tested with results that are a striking improvement. The author suggests that the change is due mainly to alterations in the physical characteristics of the flux, and it seems likely that the important points about a flux are its viscosity and the presence of small gas bubbles.

The investigation shows that steels tested under identical conditions differ greatly in their behaviour in the tinning pot. The results of an examination of a selection of steels suggest that the reasons for these differences are connected with the depth and purity of the envelope of the bar. This aspect of the problem, however, has not been studied closely, and although it is recognised that a solution is possible in the direction of modifying the steel-making process to produce bars of a type of steel containing 0·08% carbon, 0·01% silicon, 0·084% sulphur, 0·035% phosphorus, and 0·41% manganese, the present investigation deals mainly with the finishing process of the manufacture of tinplates. Large-scale experiments with a number of fluxes have brought out the importance of this factor, and have shown that comparatively small modifications in the tinning operation can change the product from mottled plates to sheets free from this defect. The prospects of a solution of the mottle problem at the tinning stage of production are very promising, and there are reasons for believing that a completely workable way out of the difficulty can be reached.

The Equilibrium of Non-metallic Systems.

Formerly it was assumed that non-metallic inclusions could be easily separated from simultaneously formed metal, on account of their having generally lower melting points and considerably lower specific gravities. It is now known, however, that these inclusions are not so easy to separate completely from the metal, and the problems that surround their cause, effect, and character, are wide and numerous. It is, therefore, significant of the importance of this question that the Iron and Steel Institute has appointed a Committee to deal with the problems pertaining to the non-metallic inclusions in steel.

It is customary to denote as slag every solid non-metallic inclusion in a metal, and a complete solution of the problem of slag in iron and steel implies a full knowledge of the equilibrium diagrams of the systems which contain metallic iron and non-metallic compounds of iron and metalloids. These include oxides and sulphides, as well as compounds of iron and other radicals, such as iron silicates. With the object of gaining information of the temperatures of solidification of these objectionable inclusions, the system FeO-MnO has been investigated by Messrs. J. H. Andrew, W. R. Maddocks, and D. Howat, while the systems MnS-MnO, MnS-$MnSiO_3$, and MnS-Fe_2SiO_4 have been investigated by Messrs. J. H. Andrews, W. R. Maddocks, and E. A. Fowler. These investigations, presented in the form of a paper, have resulted in several facts of interest and importance being brought to light.

It is evident the authors state that the micro-constituent commonly regarded as oxide is in all probability a solid solution of FeO and MnO, with a melting point varying between 1,410° C. and 1,588° C., according to the compositions, the FeO-MnO system being an isomorphous series. If the MnO content of these inclusions is high, the chance of their coalescing and floating upwards in the ingot mould is problematic. The systems MnS-MnO, MnS-$MnSiO_3$, and MnS-Fe_2SiO_4 are all eutectiferous; in every case the melting points of the eutectics lie below 1,300° C., and in the case of MnS-Fe_2SiO_4 below 1,200° C. There is the possibility—in fact, it is extremely probable—that the mixed silicates will melt considerably below 1,100° C., which is below the temperature of forging. But for the fact that the silicates ball up, rather than surround the grains, they would extremely dangerous.

It would seem a *sine qua non* that the lower the melting points of the inclusions the greater will be their tendency to rise in the mould, so that while certain compositions may actually become molten when the material is heated for forging, so long as these inclusions ball up rather than go to the grain-boundaries, such a state is less harmful than inclusions which are solid at the time the steel solidifies. Solid particles cannot possibly coalesce into large units, whereas liquid ones may, and the rate at which a segregate will rise in the mould depends upon its size, the larger the particle, the greater being the probability of its floating upwards to the head of the ingot.

Another feature of considerable interest is that MnS was found to be soluble in manganous oxide and in the silicates of iron and manganese. It would seem, however, that it is also soluble in ferrous oxide and in silicates of mixed composition. The solubility of MnS in iron and steel is infinitesimal, therefore all the sulphur in an ingot must exist either as free MnS or as MnS dissolved in oxide or silicate. These oxide and silicate inclusions will then act as scavengers for MnS, dissolving it in small quantities whenever contact between the two is brought about.

It seems a logical conclusion that the dark markings on a sulphur-print are not merely representative of free MnS, but also of every non-metallic inclusion that may occur in the steel. In other words, a sulphur-print is virtually a print showing very completely all non-metallic inclusions, the sulphur dissolved in these merely serving as a means of bringing about their detection.

Whereas the positions occupied by non-metallic inclusions in steel ingots are similar whatever be the size of the ingot, the quantitative character is not necessarily dependent on any known factor. A high sulphur content in the metal does not necessarily mean high sulphur segregation. In fact, a careful examination of data published upon segregation does seem to reveal that the problem of segregates and segregation still remains unsolved.

So-called segregation has in the past been explained entirely on the theory of the differential solidification of steel. This explanation, however, does not seem to agree with the facts, which clearly show that segregation increases from the bottom to the top of the ingot, almost irrespective of the particular lateral position selected for measuring. Does not the simpler assumption that inclusions tend to rise in the mould suffice to explain the facts? If this tendency to coalesce and rise in the mould is agreed upon, then it stands to reason that as the columnar crystals grow inwards, they will entrap the rising non-metallics according to the rate and depth to which they grow. In the centre, where the metal remains liquid for the longest time, the inclusions will have risen to a greater height, which is the case. The V-shaped inclusions in the centre may readily be explained by the fall of the liquid in the centre as the pipe cavity forms. In view of this investigation, another factor would seem to be of importance—namely, the exact melting-point of the inclusions; for the same conditions of casting and the same size of ingot, the greater would be the tendency to rise of those non-metallics which possessed the lowest melting points.

The authors suggest it would be an interesting experiment to add synthetic inclusions to a steel ingot, and to observe their behaviour. If it were found that certain compositions floated to the head more completely and more quickly than others, then the day might come when non-metallics were purposely added to the ingot in order to eliminate the whole.

The Chromium-iron Constitutional Diagram.

The investigation described in this paper by Mr. F. Adcock forms the tenth part of a systematic research on the alloys of iron which is in progress at the National Physical Laboratory under the auspices of the Alloys of Iron Research Committee. The author briefly reviews the salient features in previous work on the chromium-iron system, but apparently little recent work has been undertaken with the object of exploring the chromium-rich region of the chromium-iron diagram, although several attempts have been made to determine the melting point of chromium. There are difficulties associated with the preparation and handling of chromium and high-chromium alloys of sufficient purity, and it was realised that they could only be prepared in the absence of both oxygen and nitrogen. For this investigation the iron and chromium used were prepared by an electrolytic process, followed by repeated treatment with pure hydrogen at a temperature of 1,500° C., in order to remove oxygen, which is always present in electrolytically deposited metal. About forty alloys were prepared, and were vacuum melted in thoria-lined alumina crucibles in a valve-energised coreless induction furnace. A special difficulty occurred in making up the alloys falling within the range 16 to 40% chromium, and it was necessary to remelt these alloys one or more times before the analytical results were satisfactory. With exception of those portions of the ingots reserved for the investigation of the liquidus, all material was vacuum-annealed at 1,300° C. to 1,350° C. for 12 hours, the operation being performed in a carbon-pellet resistor furnace, the specimens being packed inside a pythagoras refractory tube, which was continuously evacuated during the process by means of a mercury diffusion pump.

Some difficulty was experienced in etching the specimens for micro-investigation. The high-purity materials, as a result of high-temperature annealing treatment, were so passive in certain composition ranges that they could not be etched satisfactorily by any of the usual reagents. This was finally overcome by using a boiling solution of 1% sulphuric acid, which apparently was the weakest solution which could be relied upon to activate all the chromium-iron series of specimens in a reasonable time.

The liquidus curve of the system was located by means of thermal observations made in a valve-energised coreless induction furnace, thermo-couples being used for the lower and an optical pyrometer for the higher temperatures. These observations were made possible by the provision of gas-tight alumina tubing. The liquidus curve shows that the temperatures of the freezing points or ranges of alloys rose steadily to that of freezing point of pure

chromium, which was recorded as 1,830° C. The freezing point of iron was determined under similar conditions, and was recorded as 1,527° C. Heating curves were taken with well-annealed samples of the alloys (up to 70% of chromium) in order to locate the solidus. The procedure was to raise the temperature of the sample steadily by gradually increasing the power supplied to the inductor coil of the furnace. When the solidus was reached there was a sudden check in the rate of heating, indicated by an inverse-rate curve recorded by the Rosenhain plotting chronograph. Owing to lack of time, the author states it has not been possible to confirm by other evidence the solidus curve established in this fashion.

The isolated γ field at the iron-rich end of the diagram was explored by thermal, dilatometric, and microscopic means. The author places the limit of the loop at 12·3 atomic %, or 11·6% by weight of chromium.

Thermal curves and two magnetic methods of investigations were used in tracing the course of the magnetic change-point from pure iron to an alloy containing 76·2 atomic % of chromium. Previous heat-treatments were found to alter the temperatures of the magnetic changes in alloys containing 40 to 70% of chromium.

The Brinell hardness, electrical resistivity, and density of the alloys are also recorded, and illustrated by curves. The paper includes appendices by Mr. G. W. Preston, on the X-ray investigation of the alloys, and by Mr. C. E. Webb on their magnetic properties at room temperature.

Fatigue Resistance of Spring Steels.

Previous investigations have shown that the fatigue resistance of unpolished spring steels is much lower than that of completely polished specimens of the same materials, the difference being due to the presence of defects at or near the surface of the metal. The present investigation by Messrs. G. A. Hankins and M. L. Becker has been carried out with the object of studying the effects of two forms of surface defects which may arise in heat-treatment —namely, small surface cracks and surface decarburisation —and, if possible, the development of methods of heat-treatment whereby such defects may be minimised or eliminated. The experiments were commenced with the approval of the Springs Research Committee of the Department of Scientific and Industrial Research, but the major portion of the investigation has been carried out at the National Physical Laboratory as part of the work on the effect of surface conditions on the fatigue resistance of steels.

The possible effect of small surface cracks was first considered, and although indications were obtained that extremely small surface markings, possibly of the nature of cracks, may occur at the surface of a quenched and tempered spring-steel specimen, such defects did not appear to be a major cause of the low fatigue resistance. The effect of surface decarburisation was studied and found to be very marked. Various heat-treatments and subsequent fatigue tests were carried out with a view to the development of a practical treatment which did not produce decarburisation. These included treatments *in vacuo*, with furnace gases under control, and in various salt-bath mixtures.

General consideration of the results of this investigation appears to give ample confirmation to the suggestion, put forward by Dr. Hankins in a previous paper, that surface decarburisation was a most important factor in the low fatigue resistance of unpolished specimens of spring steel. It is true that positive evidence was not obtained in all cases that actual surface decarburisation had occurred when the fatigue resistance was found to be low, but in nearly every case in which low fatigue values were obtained either decarburisation was present or else a soft surface layer was indicated by hardness tests. In the earlier stages of the investigation many observations of the structures at, or near, the surfaces of the specimens were made, but direct interpretation of the micrographs sometimes presented difficulties. For evidence of decarburisation it is preferable for the material to be normalised, but, according to the conditions prevailing, the normalising process may itself be sufficient to cause marked additional decarburisation or carburisation. Microscopic examination of a surface after normalising is, therefore, likely to be misleading where the original decarburised layer is possibly less than 0·001 in. deep. Careful preservation of the edges of the section when cutting is also necessary, and in the present work closely-fitting tubes, electrolytically deposited layers of copper, and mounting in fusible alloys were employed.

The mechanical explanation previously advanced—namely, that fatigue cracks commence in a soft surface layer, which has an intrinsically low fatigue resistance, and are then propagated by stress concentration into the more highly resistant material below, provides a rough general explanation of the fatigue failures at low stresses obtained in the present experiments. This explanation, however, can hardly be applied quantitatively, but the results of the tests in which different times in the heating medium were allowed, suggest that the greater the decarburisation of the surface layer the lower is the fatigue resistance, and support the mechanical explanation in that it is probable that the intrinsic fatigue resistance of the surface layer is roughly proportional to its hardness and diminishes with a decrease in the carbon content.

The present work has been largely confined to two high-grade spring steels, but it is suggested that the experiments carried out have been sufficiently extensive for the conclusion in regard to decarburisation to be generally applicable to hardened and tempered steels. In effect, where a high fatigue resistance is required in a hardened and tempered steel, it is necessary for surface decarburisation in the heat-treatment to be eliminated or reduced to a minimum. This only applies, of course, when the original surface is not decarburised as a result of earlier operations. In the case of normal spring-steel plates, this appears to be the case, and if it is desired to utilise the fatigue-resisting properties of the body of the material without any machining at all, it appears to be necessary to apply some form of carburising treatment to improve the surface layers. Experiments are now in progress in order to determine whether a carburising process of this nature results in improved fatigue resistance of unmachined, hardened, and tempered spring plates and forgings.

It is proposed to attempt the development on similar lines of heat-treatments, which increase the carbon contents in the decarburised surface layer that is produced during the rolling stages of manufacture of spring-steel plates.

Steel Ingots.

Considerable attention has been directed to the improvement of steel, during recent years, by rendering it more uniform, and investigation has disclosed an interesting relation between the microscopic structure of a steel piece and its applicability. It has been found that the degree of uniformity is determined mainly by the structure of the ingot, that crystallisation and segregation are very important, and that their influence may be changed by hot forging, but never entirely eliminated.

The subject was discussed in a paper by Dr.-Ing. Bernhard Matuschka, in which he dealt with the problems of solidification and crystallisation, as well as the influence of casting temperature and undercooling of the steel. Concerning the phenomena of the freezing of steel, he said the moment the liquid steel is cast into a mould it can no longer be influenced at will, but is subject to the laws of the freezing of liquid metals. The conditions which determine solidification and crystallisation may be classified as external and internal. External conditions are those which initiate and control the cooling of the steel, and are determined by the mass and condition of the mould. Internal conditions are those which govern the cooling effect within the ingot. The internal conditions are determined by the physical and crystallographic properties of the steel.

The author has investigated the cooling effect of the mould and the influence of the casting temperature on the progressive solidification of the steel, and, as a result of his investigations, he concludes that the solidification and crystallisation of steel ingots are absolutely regular phenomena. The external conditions which initiate them and cause them to continue are determined by the cooling of the mould. The internal solidification conditions determine the solidification and crystallisation in the ingot under given conditions of heat dissipation by the mould. They are influenced principally by the casting temperature and the undercooling capacity of the steel. The paramount importance of one of the factors is determined by the composition, and the physical and crystallographic properties of the steel. In all cases a low casting temperature and maximum purity make for finer primary crystallisation and less segregation—that is, improved quality due to increased uniformity.

Production Economy in Iron and Steel Works.

The first part of this paper by Dr. Ing. Otto Cromberg, was presented at the last annual general meeting of the Institute. In that paper he discussed the scientific organisation of manufacturing operations, and stressed the need for carrying out time studies, the object being to determine accurately the relationship in time between the worker, the equipment available, and the material being manufactured, so that the optimum value of the cost of manufacture can be obtained.

In the second part of this subject the author deals primarily with the costs of production. He indicates how, by means of the schedule output values as derived from time measurements, the calculation of costs of production can be organised and carried through, in order to obtain a regular comparison of schedule values with actual values. These considerations concerning costs of production are intended to point the way out of the present situation, in which the management is not informed soon enough, and is consequently unprepared with measures before losses have been incurred. The system advocated by the author can be briefly summarised as follows:—

The works operations are first analysed by means of time studies and similar practical investigations. The investigations do not stop short at the simple recording of the working conditions as revealed by the studies, but they must result in the critical discrimination between what is economical and what is uneconomical. The first thing to be determined is the time of manufacture or "following time," free from stoppage or loss. To this uninterrupted time must be added the loss-of-time factor, which must also be specially calculated.

It is imposed on the department as a duty to give the outputs proved to be practically attainable. This is where the intensive training of the men becomes necessary. It is not enough just to criticise, but instruction must be given as to ways and means whereby an improvement in the methods of working can be actually achieved. No progress will be made until the training has been properly carried out down to the last individual worker.

Workmen and foremen alike must be encouraged by means of a remuneration in relation to the output to take an interest in the economic management of the undertaking. For the workmen this can be most conveniently arranged by means of a time-rate contract. For the foremen and departmental managers the reward takes the form of a bonus, according to the cost of production.

The recording of operations should be done in such a manner as to enable a daily comparison to be made between the schedule and actual output, and the data derived from the study of works operations must be available for calculating the cost of production. The necessary records for the control of operations should be made in a form which can simultaneously be used for checking the calculations of costs of production. These calculations include both the accountancy in connection with different classes of product and that for keeping a record of the conditions in the works. Special problems, such as the working out of the most economical method for carrying out particular operations, the influence of the rise and fall of certain kinds of costs, such as wages, raw materials, etc., on the cost of the manufacture of the product, can be solved without difficulty with all the accumulated data which thus become available.

Nitriding Special Steels.

This paper gives a detailed explanation of the process of nitriding as carried out productively by a well-known Sheffield firm with which the authors, Messrs. W. H. Cunningham and J. S. Ashbury, are associated. A description of the treatment of articles to be nitrided is given. With each charge one or two test pieces are placed among the articles to obtain a representative nitride case. The nitriding period is taken from the time the box pyrometer registers 500° C., and the temperature is kept between 495° C. and 505° C. throughout the run.

The authors have found from experience that a solder consisting of 80 parts lead and 20 parts tin affords the most efficient protection for parts not required to be nitrided, and they discuss methods of protection against hardening. They have found that no distortion takes place during nitriding, provided the piece is of uniform section, has no protected portions, and has been stabilised thoroughly to remove any machining strains; but there is a slight increase in size. This growth is very uniform, and appears to be a function of the time, the temperature, and the percentage of gas dissociation. The figure 0·0012 in. is given as very nearly constant for the growth which takes place on solid pieces from 1 in. to 12 in. in diameter. Although the growth is uniform with uniform sections, it differs with varying sections.

Hardness testing of the nitrided part is carried out by means of a Firth hardometer capable of exerting a load of 10 kilogs. or 30 kilogs., and it is the authors' practice to obtain diamond hardness numbers varying from 1,020 to 1,170, and any tests falling below 1,020 are investigated, and, if necessary, the articles in the batch are re-nitrided.

The authors discuss surface defects, and assert that the majority of these defects occurring on nitrided articles can be traced to decarburisation resulting from mishandling in previous operations. The importance of the strength of core is rightly stressed, and the heat-treatment practice adopted gives interesting mechanical properties. The nitriding steels with which the authors deal are manufactured in six grades, the four most generally used having a carbon content ranging from 0·20 to 0·55%, other elements being the same for all types. The carbon content within these limits has no effect on the hardness of the nitride case, and is governed solely by the mechanical properties required of the core. Examples of the mechanical characteristics of the steels in test-pieces made from $1\frac{1}{8}$-in. hammered bar, after oil-hardening at 900° C., and tempering at 600° C. for grade 1, and 650° C. for grades 3, 5, and 7, are given in Table I.

TABLE I.

Grade.	Carbon, %.	Max. Stress, Tons per Sq. In.	Elongation, %.	Yield Point, Tons per Sq. In.	Impact Value, Ft.-Lb.
1	0.46 to 0.55	90.4	11.0	83.6	19
3	0.36 ,, 0.45	77.4	13.5	69.7	38
5	0.26 ,, 0.35	56.8	18.5	44.0	57
7	0.20 ,, 0.26	48.8	22.5	32.8	73

The paper concludes with a general review of the furnace routine adopted. The need for allowing the nitrogen to circulate freely around the articles is stressed, and the use of nickel wire grids to separate various layers is recommended.

The Structure of Nodular Troostite.

Col. N. T. Belaiew, in a paper on the structure of nodular troostite, briefly reviews the work of previous investigators, and refers to his views on the stereometry of the pearlite grain given in a paper read before the Institute in 1922. In the light of considerations advanced, the author examines a typical nodular troostite with the object of determining its structure, and concludes that the structure of primary nodular troostite is lamellar, like that of lamellar pearlite; the interlamellar distance Δ_0 computed by the indirect method of dividing $\Delta\omega$ by sec ω gives the value 100 $\mu\mu$; accordingly, the structure of troostite can only be resolved under high magnifications and with lenses of high aperture. Under a magnification of 3,000, and with an aperture of 1·40, the structure of about 50% of all the grains can be resolved; the whole area, therefore, appears as an aggregate of grains, some clearly lamellar, some faintly striated, and some structureless. An analogous micrograph may be obtained from ordinary pearlite taken with "empty" magnification—that is, with such an aperture that the resolvable distance ϵ is larger than the interlamellar distance Δ_0.

That the hardness of troostite seems to be constant and in the vicinity of 450 Brinell; thus, troostite does not comply with Green's formula $H \times \Delta_0 = 79 \cdot 59$, and whilst its hardness is much higher than that of pearlite (200 to 300), it is considerably lower than it would be if it complied with that rule.

Lamellar structures intermediate in hardness and in values of Δ_0 correspond to sorbite. The latter seems to be more closely associated with pearlite than with troostite; still, the demarcation line is brought into evidence by the fact that sorbite does not follow Green's rule, that its Δ_0 is below the critical value of 260 $\mu\mu$, and that there is a range of velocities of cooling, from 5° to 15° C. per sec., which are typical for sorbite. Thus, whilst possessing structurally some features common to all lamellar structures, and being sharply divided from the product of a full hard quench—martensite—pearlite, sorbite, and troostite ought to be considered as distinct and different constituents of steel.

The Origin of Banded Structure.

The characteristic laminated microstructure of a hot-worked mild or medium-carbon steel has been investigated by a number of workers, but the cause or causes to which this structure is due are still somewhat uncertain. Various suggestions have been made as to probable causes, but apparently there has been no attempt critically to consider them. The critical study of the subject in the paper by Messrs. F. C. Thompson and R. Willows is an effort to bridge the gap. The work described has extended over several years, and covers investigations into all the hypotheses suggested—viz., the inclusion theory, the phosphorus theory, the theory, suggested by Benedicks and Löfquist, that working the steel may be the cause, and the oxide theory.

The results of this work, taken in conjunction with those of previous investigators, indicate that slag-bands in electrolytic iron, carburised and heat-treated *in vacuo*, or in steel annealed as small specimens at a sufficiently high temperature, do not lead to the formation of the structure under consideration. Even when electrolytic iron is phosphorised as well, the result is just the same. That the banding may be eliminated by a high-temperature annealing treatment in small specimens, but still persists after similar treatment in large ones, is, the authors conclude, inexplicable in terms either of the pure inclusion or of the phosphorus hypothesis. It is, however, to be expected on the basis of a theory such as that which ascribes the banding to oxygen, which demands the removal of a gaseous product. The greater the surface area and the smaller the distance through which the gas must diffuse, the more rapidly should the banding disappear.

The authors, as well as other investigators, have found that it is at the surface that removal first occurs, and that there is no recorded instance of this order ever being reversed is confirmatory of these ideas.

Very strong evidence in support of the oxygen hypothesis is provided by the fact that oxidation of mild steel, followed by carburisation, can result in a lamination exactly analogous to that observed in ordinary rolled mild steel. The only elements taking part in this series of reactions are presumably iron, carbon, and oxygen, and that the carbon cannot be solely responsible is shown by the fact that a given steel can be obtained with or without the banding without any appreciable change in the analysis.

The non-removal of the structure by heating in hydrogen, which is at first sight unexpected if the oxygen hypothesis is correct, is explained adequately by Whiteley on the ground that the steam formed diffuses very slowly, the rate of the reversible reaction being correspondingly low.

Carbon monoxide removes the banding to a depth slightly exceeding that of visible carburisation without changes in the distribution of visible inclusions and without any removal of the phosphorus. Slag, however, exerts an indirect effect, probably as a result of the oxide in solution around it. Where this oxide is removed from solution, inclusions exert no influence.

The whole of the evidence is consistent with the view that Giolitti's theory, that the inclusions normally exert an oxidising influence upon the steel in their vicinity, is true, and cannot, so far as the authors can see, be reconciled with the requirements of any other hypothesis.

What evidence is available suggests that the original cause of the differential oxygen concentration lies in the coring of the crystals formed during solidification, and is not due to any mechanical influence—other, of course, than the distortion of the dendritic structure—such as that suggested by Benedicks and Löfquist.

The Institution of Automobile Engineers.

The opening meeting of the session of the Institution of Automobile Engineers, which took place at the Royal Society of Arts recently, was remarkable for a number of interesting ceremonial innovations. The retiring President, Sir Herbert Austin, took the opportunity of introducing to the members the newly elected members of Council, Messrs. D. E. Batty, Oliver Lucas, P. C. Kidner, G. J. Rackham, A. A. Rowse, and Capt. J. S. Irving, following which short speeches were made by Mr. C. R. F. Engelbach (Vice-President), and Mr. W. J. Tennant, who is retiring from the Vice-Presidency for reasons of health.

After Sir Herbert Austin had introduced Mr. W. A. Tookey, the President for the session 1931-32, to the chair, he was presented by Mr. Tookey with a commemorative certificate and badge, a happy idea, which it is proposed to perpetuate.

One of the earliest duties of the new President was to present to Mr. Basil H. Joy a leather travelling case and an address from the Officers and Council of the Institution to mark the completion of a period of twenty-one years as Secretary of the Institution. Mr. Tookey then delivered his presidential address, entitled "The Internal Combustion Engine and Its Performance," a vote of thanks being subsequently proposed by Mr. L. H. Pomeroy (Vice-President).

The President delivered his address at Birmingham and Bristol on October 5 and 8 respectively, and it should be noted that he is due at Glasgow, Leeds, and Manchester on October 26-27 and 28 respectively, and tickets to admit visitors to any of these meetings may be obtained on application to the Secretary, the Institution of Automobile Engineers, Watergate House, Adelphi, London, W.C. 2.

Crompton Medal.—The Crompton medal, which is awarded annually by the Council of the Institution of Automobile Engineers for the best paper read before the Institution during the session, has been awarded for the session 1930-31 to Dr. S. J. Davies and Mr. E. Giffen, of King's College Engineering Department, for their paper entitled "Injection, Ignition, and Combustion in High-speed Heavy-oil Engines," the presentation being made to the authors by Sir Herbert Austin at the opening meeting of the session on October 1.

It will be recalled that this paper was read at a joint meeting of eleven Engineering Societies in March last, an innovation which proved so successful that a similar meeting is to be organised later in the present session.

Recent Development in Tools and Equipment

REGRINDING MACHINES FOR OUTSIDE JOURNALS.

Designed for retruing by grinding, the outside journals of such wheel sets as carriage wagon and tender, a modern machine, manufactured by the Churchill Machine Tool Co., Ltd., is capable of remarkably high output. In addition to being designed to remove metal at a very high rate with two wide-faced grinding wheels, the entire machine can be easily operated and the facilities provided for handling even the heaviest wheel sets reduce idle time to a minimum and enable it to be conveniently operated by one man.

This machine is designed with two heavy grinding wheelheads, one on either side of the bed-plate, as shown in the accompanying illustration, which are provided with four speeds of power traverse and variable automatic feed. These two movements are also arranged to be operated by hand. The wheelheads are designed to facilitate the use of wide-faced wheels for grinding by the plunge method, as well as by being traversed. Mounted on balancing-type wheel collets, the grinding wheels are secured to the wheel spindle by the flange method. To lengthen their useful life, the grinding spindles are of Nitralloy steel, which, after "nitration," are ground and lapped into their large-diameter bronze bearings. Lubrication of the bearings is by a positive pump supply with a visible oil flow, and incorporates a filter for the purpose of ensuring that only clean oil reaches the bearings.

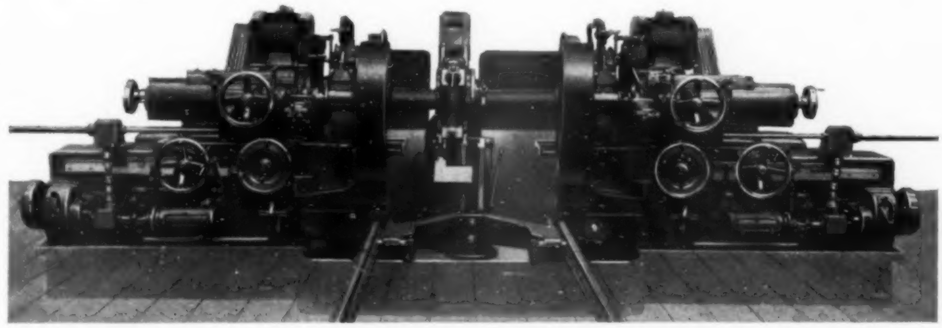
The length of power stroke of the wheelheads is controlled by adjustable trips mounted on a rack, which is situated with the other controls on the front of each box bed. Automatic feed, which is variable, can be applied with wheelhead, either traversing or stationary. An adjustable trip is incorporated for the purpose of cutting out the feed at any desired point.

For grinding, the wheel set is carried on the dead centres of two heavy adjustable heads, each centre having axial adjustment. Rotation of the wheel set is by a worm and split worm-wheel driver, which transmits its motion to the wheel set by a dog and carrier peg. A constant-speed motor drives the work, any variation of rotational speed being adjusted by interchangeable pulleys. By a combined clutch and brake the rotation of the wheel set is arrested immediately the drive is disconnected.

This machine is fully equipped for wet grinding, and hinged splashguards are arranged to enclose the tyres of the wheel set when the machine is in operation. To meet special requirements, it can be equipped with tool slides, which mount on the dead-centre heads for the purpose of turning end collars, dust-cap seatings, or for removing an excessive amount of metal from journals. Truing devices, which form an integral part of each dead centre, can be used for either straight or radius truing. The tank containing oil for the hydraulic jack, incorporated with the machine, and the reservoir for the coolant form a separate unit, which is located at the rear of the machine.

One of the important features of this design is the self-contained hydraulic lifting appliance which enables the wheel set to be inserted in the split worm-wheel and centred with preconceived facility. This hydraulic jack, which is operated by a constant delivery gear-type pump, is controlled by a lever placed in a position where the operator has full view of the centring of the axle.

This machine is capable of handling efficiently all wheel sets with outside journals, including the heaviest types used, and as it is entirely self-contained, being independent of cranage, and is fitted with separate motors driving the various motions, it is a valuable machine for dealing with work with which it has been specially designed to cope.



Special Regrinding Machine for Outside Journal.

PNEUMATIC TOOLS.

Pneumatic tools have been improved and developed to such an extent that they are now essential appliances for a wide range of operations. Not the least useful are those that have been designed as percussion tools. A new range of this type of tool has been recently placed on the market by Sir W. G. Armstrong Whitworth and Co. (Engineers), Ltd., of Newcastle-on-Tyne. This firm have over thirty years' experience in the design and manufacture of pneumatic tools of all descriptions, but recently this section of their products has been completely redesigned.

The new range includes such tools as riveting hammers, chipping hammers, scalers, jam riveters, sand rammers, drilling machines, grinders, concrete breakers, etc., and they embrace a few outstanding features. The number of different sizes of each type of tool has been considerably increased in order to meet individual requirements more exactly. For instance, this firm now produce six different sizes of riveting hammers and five sizes of chipping and caulking hammers, but duplication of components has been avoided because, in each of these groups, all parts, with the exception of cylinders and pistons, are interchangeable from one size to another. This has an important bearing on spare-parts service.

A new riveting hammer is particularly interesting in view of its high performance in comparison with its weight. This tool weighs little more than 17 lb., and the makers claim that it will close $\frac{3}{4}$ in. and $\frac{7}{8}$ in. hot cup-head rivets without any difficulty. This low weight is of particular benefit to the operator, and in common with the other tools of the range the air consumption is exceptionally low.

In tools of this type it is important that the action should be free from recoil, the design and construction perfect,

yet simple, and the workmanship such as will guarantee their reliability and durability in service. It is with these features in view that Messrs. Armstrong Whitworth have improved and developed the new range of tools which are giving excellent results. It is also important to note that, in addition to the maintenance of adequate stocks of pneumatic-tool equipment in various parts of the country, a fleet of service vans, in charge of competent service engineers, is in operation throughout Great Britain. These vans are fully equipped with new tools and spares, and frequent visits are made to users of Armstrong Whitworth tools to ensure that satisfactory service is being given.

BEARING METAL CONTAINING GRAPHITE.

The lubricating properties of graphite are well known, and its use in bearings has been long appreciated, but, with the possible exception of cast iron, no metal has previously been developed which incorporates graphite in its composition in such a way that lubricating qualities are improved. With this object in view, Mr. H. Borofski has been experimenting for the last fifteen years, and has, it is claimed, recently produced a bearing metal, known as "Boroto." This alloy can be melted and remelted in any foundry. Although his first process to manufacture a bearing bronze was patented in 1912, the difficulty of retaining the graphite in the metal during the remelting process was not overcome by him until 1931.

It is claimed that "Boroto" bearing metal can be made in any desired alloy of white metal to suit various requirements, but so far the inventor has concentrated on five different alloys which, in practice, have proved to be most satisfactory and to fulfil all requirements, even those of heavy Diesel engines. The manufacturing process is considerably cheaper than that of ordinary bearing metal, containing large proportions of tin.

The melting and casting of these new alloys do not vary in the slightest degree from that of ordinary white metal; in the original manufacturing process graphite is permanently incorporated in the metal, and none of it is lost in remelting. Not only can the alloy be used for bearings, but, contrary to the usual practice, for bushes as well. For this purpose a bronze or brass tube is lined to any desired thickness with graphite-containing white metal.

The possibilities of these alloys offer an improvement so far as bearings are concerned, and it is important to note that in order to afford users the opportunity of testing for themselves their efficiency, the manufacturers state that they are prepared to supply complete bearings or bushes to user's own specification, free of charge, to prospective users. Inquiries should be made to Mr. E. Siegrist, 22, Henrietta Street, Strand, London, W.C. 2.

A NEW RECORD IN WORM-GEAR EFFICIENCY.

THE HOLROYD-WALKER WORM-GEAR.

John Holroyd and Co., Ltd., of Milnrow, have recently perfected and put on the market a new worm-gear known as the Holroyd-Walker worm gear. This gear embodies a new form of worm thread which gives a larger contact than any other worm gear, and is of such form that it automatically forces the oil between the tooth surfaces, and sustains a permanent oil film even under extremely heavy loads.

It has been tested at the National Physical Laboratory on the Daimler-Lanchester worm-gear testing machine and established a new world's efficiency record, beating the previous record by a very considerable margin. The gear showed an efficiency, under the maximum load which the testing machine is capable of exerting, of 97·6%, and this figure was sustained over a series of readings, both at maximum and lighter loads, and at various speeds.

The gear tested was an entirely standard product, and was not run-in or bedded down in any way previous to the test. It was taken straight from the gear-cutting machine and assembled in the testing machine, and after about two hours' running it registered an efficiency of 97·6%. It is a remarkable fact that the highest efficiency of 97·6% was obtained under the maximum test load, and it is important to note that this gear has given 97·6% at several speeds and several different conditions of loading.

The following are the results obtained under various speeds at the maximum load of about 850 lb./ft. torque on the wheel. For purposes of comparison the figures from the previous world's record are also given. Both gears were 6-in. centres and ratio approximately 3·8 to 1.

Speed of Worm Approx.	Previous Record Efficiency. A.	B.	Efficiency of Holroyd-Walker Gears.
	%	%	%
750	95·4	96·2	96·3
1000	95·5	96·5	97·6
1250	95·5	96·5	97·2
1500	95·8	96·7	97·5

It will be noticed that two sets of figures are given for the previous record. The figures in column A were obtained on a pair of gears not run-in after machining. The figures in column B were obtained on a worm-wheel run-in for 18 hours before test. The Holroyd-Walker gear was not run-in or touched in any way before the test, and it will be seen that it shows a distinct increase on both the other sets of test figures.

A further test on the Holroyd-Walker gear showed an efficiency of 97·6% under maximum load and speed, viz., 86 h.p. at 2,000 r.p.m. It is significant that in the previous record the highest efficiency of 97·3% was obtained when transmitting only 19 h.p. at 1,500 r.p.m.

Comparing the Holroyd-Walker gear with column A (both gears not run-in), it will be seen that the average power lost in the Holroyd-Walker gear is about 2·6% of the input power, whereas in the previous gear the power loss was about 4·5%—*i.e.*, about 75% more power loss. As this waste power is converted into heat and causes wear and abrasion, it will be appreciated that the Holroyd-Walker gear will stand about 75% more load than the previous gear without increasing temperature rise or rate of wear.

The feature which has enabled these remarkable results to be obtained is the fact that the worm thread is of such a form as to force the lubricant along the line of contact between the tooth surfaces, and maintains a tenacious oil film between the worm and wheel. The gear is provisionally protected, and will be on view at the Commercial Exhibition at Olympia.

Aluminium Bronze Die-castings.

(*Continued from page* 172.)

3. It does not crystallise when submitted to constant stresses, shock, change in temperature, or alternating stresses.
4. It does not scale.

The possibilities of its wide application need little stressing, since the metallurgist has produced in aluminium bronze a material of beauty and strength that is indifferent to normal corrosive influences. Engineers and designers, after giving its properties careful study, will appreciate that they have at their disposal a material which can be extensively used in their assembly with the minimum of machining costs. Apart from very small holes and screw threads, machining depends upon the class of work being done, but it is wise to state limits of ± .010 to .005 in.

The application of the material range from the giant bearings for bridges to the delicate beams of a laboratory balance, from the worm-wheel of a Ford truck to the smallest die-cast brush-box as used in electric motors. Even the artist has a material here of highly decorative value, possessing a colour of 10-carat gold, which can be varied at will to give any desired artistic effect.

Protection of Metal Parts of Aircraft against Corrosion.

This subject was discussed by H. Sutton, M.Sc., A.F.R.Ae.S., in a paper he presented before a meeting of the Royal Aeronautical Society on October 15, and is published here in an abridged form.

DURING the past few years much attention has been paid to the protection of metal parts of engineering structures of all kinds against corrosion. The problem of protecting metal structures against deterioration is now recognised as of primary concern both to users and to manufacturers. Corrosion prevention is an economic problem, and its cost must be based on the cost of preventative measures compared with the loss directly and indirectly due to deterioration. In those sections of industry in which marked advances have occurred in corrosion prevention, the advances can be seen to be the result of close co-operation between the laboratory, manufacturers, and users.

Protection of Steel Parts of Aircraft.

Marked developments in the so-called "stainless" or "non-corroding" steels have taken place, and in this country application of these steels in aircraft construction has now assumed extensive proportions. It is now recognised that the high degree of resistance of these steels to corrosion is due to the protective effect of the films which form under normal conditions of use upon the exposed surface, and to the rapidity with which such films form again at places where rupture of the original film occurs by reason of chemical attach or mechanical breakdown. The film-building properties are gained by the addition of special elements, notably chromium, to the steels, and the attainment of a high degree of corrosion resistance in this way may, therefore, be regarded as the result of the application of a method of protection.

Stoving enamels, Mr. Sutton stated, have found extensive application, and have usually been found satisfactory when good-quality enamel is applied under appropriate conditions and properly stoved. The use of temporary preservatives on raw materials and on metal parts after manufacture to provide protection during storage, or during intervals between successive stages of manufacture, has proved of benefit.

Cadmium Plating.

Electro deposits of cadmium on steel parts have been found to be capable of affording a high degree of corrosion resistance, particularly where mechanical abrasion or severe exposure to the influences of weather do not occur. The degree of adhesion of deposits of cadmium and other metals can usually be observed by simple bend tests on samples of small section in suitably ductile materials—*e.g.*, mild sheet steel, streamline wire, or tie rod. The advantage to the operator gained by the inclusion of samples for subsequent application of simple tests is one that is sometimes overlooked in the haste to maintain the desired flow of production work through the bath.

Cadmium plating of streamline wires and tie rods has generally given good results, but the author stated that several cases of unsatisfactory performance of such wires have been caused by imperfect cleaning of the wires before plating; too thin deposits, due possibly to bad contacts during plating; splashing of plated wires with solution or washing-water during standing in the plating shop; and to unsatisfactory adhesion of the deposits.

The use of stainless or monel-metal tabs on cadmium-plated wires appears to have much less tendency to cause corrosion of the cadmium coating and steel under the tab than was the case with the brass tabs formerly used.

Some difficulty has been experienced in securing the high degree of adhesion of enamel and paint films to cadmium-plated surfaces. By the use of suitable under-coatings a very high degree of adhesion may be obtained, but the application of another separate coating and the extra time involved by the subsequent drying are expensive. Attention is therefore being paid to the matter of developing enamels capable of adhering firmly to cadmium-plated surfaces.

Zinc Plating.

Zinc-electro deposits have found extensive application in the protection of aircraft components. The electro deposits are usually harder than those of cadmium, and are probably slightly more durable under normal conditions of use.

While excellent deposits of zinc can be obtained from the sulphate or chloride type of bath, deposition on steel parts is usually effected in zinc-sodium-cyanide baths owing to the better "throwing power" obtained with the latter. Zinc is less readily deposited from cyanide electrolytes than cadmium, and more careful control of the composition of the bath is required to ensure good and consistent results.

Several processes are employed for the production of zinc coatings by the hot-diffusion or "Sherardising" method. This method serves a useful purpose, particularly in the protection of steel tubes and fittings of such shape as to prevent adequate deposition of metal by electrolytic methods on recessed parts or internal surfaces. The protection afforded by this means is usually not quite so good as that afforded by electro-deposited zinc coatings of good quality, and considerable variation in thickness of the coating may occur.

Electrolytic Nickel Coatings.

Heavy nickel deposits applied to steel surfaces cleaned by electrolytic pickling have been used for the protection of exhaust manifolds and pipes of engines, the protection being excellent at elevated, as well as at normal, temperatures.

Since the efficiency of the protection afforded by protective metal coatings is influenced by the thickness of the coatings, the author referred to methods employed to determine the thickness of the coatings.

A sample of regular shape is taken and weighed. The area of coated surface in square centimetres is calculated from direct measurements. The sample, held by a piece of aluminium wire, is then immersed in a small quantity of cold concentrated nitric acid until all the metal coating has dissolved. When the action has ceased the sample is removed from the acid and rinsed with water, the washings being collected in the beaker. The sample is finally rinsed with alcohol, dried, and weighed again.

A small quantity of iron is invariably dissolved away with the coating, due to local dilution of the nitric acid during the solution of the coating and also during the subsequent rinsing. This is separated from the nitric acid with ammonia and determined volumetrically. This weight of iron deducted from the loss in weight of the sample gives the weight of metal coating. The weight of coating in grammes divided by the density in grammes per cubic centimetre gives the volume of the coating in cubic centimetres, and this, in turn, divided by the predetermined area of the coated surface gives the thickness of coating in centimetres.

The densities in grammes per cubic centimetre are: Cadmium, 8·6; zinc, 6·9; nickel, 8·8.

Protection of Steels against Oxidation at Elevated Temperatures.

The prevention of scaling of exhaust pipes and manifolds of aero engines is a problem which has received some attention recently. Among the various methods which have been investigated may be mentioned nickel plating, "calorising," aluminium spraying, and aluminium dipping.

In the case of electro deposits of nickel, coatings of the order of 0·003 to 0·005 in. in thickness are usually applied, the steel having been pickled electrolytically. With this method there is the difficulty of securing a high degree of protection on the interior of manifolds, etc. This, however, is probably not serious, since the amount of oxidation

which occurs on the inside of a manifold or exhaust pipe is small compared with that which takes place on the outer surface.

The "calorising" process is one in which the steel parts, after having been cleaned by sand-blasting or other suitable means, are packed in a sealed container with a mixture consisting of aluminium powder, alumina, and a little ammonium chloride and heated to approximately 680° C. for one to two hours. At the surface of the steel an aluminium-rich alloy layer is formed which affords considerable protection to the steel against scaling.

Spraying steel parts with metallic aluminium by means of a special pistol and then heating the sprayed parts to effect alloying between the coating and the basis metal furnishes another useful method of increasing the resistance of steel components to oxidation or scaling at high temperatures.

Aluminium dipping has also given very promising results as an anti-scaling process. Special means have to be adopted to secure uniform alloying of the aluminium with the basis metal.

General.

The success of the various methods of protection is always liable to be affected by the original condition of the material. It is therefore of highest importance to be certain that the material is in the correct condition of heat-treatment, is satisfactorily free from spills, cracks, seams, discontinuities, and similar defects, which form easy points of attack and paths of progress for corrosive agencies. This is particularly the case with duralumin, which is profoundly affected by the conditions of the heat-treatment and ageing to which it has been subjected. Even the best-known methods of protection have been known to fail on duralumin incorrectly heat-treated.

Pulverised Fuel for Ships.

COINCIDENT with the slump in shipbuilding, the progress of pulverisers has not been so rapid on sea as on land. Signs of impatience have been manifest by many who a few years ago hailed powdered fuel as the solution to many marine steam-raising problems, and as the salvation of the coal-mining industry. Indeed, many of those naturally biased against coal-firing in any form have gone so far as to claim that pulverised fuel firing at sea has not justified itself. The record of the Clarke-Chapman "Resolutor" pulveriser dissipates any such pessimism.

This Gateshead firm have already installed the "Resolutor" pulveriser plant in several vessels, including the pioneer ship, the s.s. *Berwindlea*, and all the vessels are returning, without exception, excellent results, and concrete figures can be supplied to support them. It is gratifying to note that in addition to an order booked a few weeks ago for powdered fuel equipment for a Japanese steamship, another order has been received from Japan, which will bring the number of vessels fired by the Resolutor pulveriser up to nine. The last two orders have only been placed as a result of an exhaustive examination of pulverised fuel equipment by Japanese engineers.

The new installation is to consist of three No. 2 Resolutor pulverisers, each capable of dealing with one ton of coal per hour, comprising pulverising chamber, separator, primary air fan and driving engine, which in this machine are all included in one unit on the same bed-plate. The drive is by means of high-speed steam engines delivering 30 h.p. at 1,450 r.p.m., with a steam pressure of 100 lb. per sq. in., and exhausting against a back pressure of 10 lb. per sq. in. The fuel will be conveyed by the Clarke-Chapman patent ring main system, and "Woodeson" patent short-flame burners will be employed.

The order includes all necessary equipment, such as air pipes, elevator, the Clark-Chapman ash ejector plant, crushers, etc.

The world rights for the manufacture and sale of the Resolutor pulveriser are divided between Messrs. Clarke, Chapman and Co., Ltd., of Gateshead, who have received order for the equipment of five vessels, Messrs. Fours Stein, of Paris, who have equipped three vessels, and Messrs. Kohlenstaubfeuerung, of Berlin, who have equipped one vessel, making a total of nine in all.

The rapidity with which this order has followed the previous one indicates that pulverised fuel firing at sea is a proposition that is very much alive, and that the Gateshead firm are ready to take immediate advantage of the shipbuilding boom when at long last it materialises.

Catalogues and Other Publications.

A very comprehensive and informative catalogue has recently been published by August Muffle Furnaces, Ltd. Originally formed to develop the muffle furnace, this company has made extensive progress, and to-day has an enviable reputation, not only in the manufacture of furnace equipment for all purposes, but in all forms of foundry appliances.

Much energy has been directed to the design and manufacture of foundry equipment, and the efficient condition of many foundries is the best evidence of the company's success in this field. The complete installation and equipment of foundries is undertaken, including the designing and layout of proposed shops and plant to the actual operation of the completed units. The catalogue includes a chart which displays plant for a typical modern continuous-casting system, together with sand-handling and reconditioning plant. All who are interested in industrial furnaces for any purpose, whether fired by coke, gas, oil, or pulverised fuel; foundry equipment, particularly sand-handling and reconditioning plant; or conveyer plant, should see this publication, which can be obtained on request from August Muffle Furnaces, Ltd., Halifax.

The English Steel Corporation of Sheffield has recently issued two interesting brochures, one dealing with forged drums for high-pressure boilers, and the other giving information on this company's magnets and magnet steels. Both are neatly prepared and well illustrated, the former giving photographic reproductions showing the various operations involved in the production of forged drums, from the ingot to the finished product. This company has facilities for producing forged drums up to over 100 tons in weight.

The second brochure illustrates, by means of test figures and graphs, the advantages which can be obtained by using these steels. This company has a special research department devoted to the subject of magnets and magnet steels, and recent advances in the construction and design of permanent magnets are, in no small measure, due to the research work done at this firm's works. The principal magnet steels produced at these works, of which particulars are given, are: 6% tungsten, 9% cobalt-chromium, 15% cobalt-chromium, and 35% cobalt-chromium-tungsten steels. In addition reference is made to special steels for electrical equipment. These interesting brochures are available on application to the company's offices at Sheffield.

The Brooke Tool Manufacturing Co., Ltd., Warwick Road, Birmingham, has sent us a brochure containing full information regarding their taps with ground threads. All threads are relieved, and the cutting qualities of the tap are consequently increased, with a resulting longer serviceable life. The demand for extreme accuracy has resulted in the production of these precision-ground thread taps, and users should have this brochure at hand for reference.

The Electrical Equipment and Carbon Co., Ltd., 107-111, New Oxford Street, London, W.C. 1, supply special fittings for overhead lines, and have recently published a brochure illustrating and giving full particulars of a wide variety of line clamps, joints, terminals, etc.

G. W. B. Electric Furnaces, Ltd., Elecfurn Works, Holloway, London, N. 7, have issued an instruction card entitled, "Practical Hints for Use in the Hardening Shop." The card measures 12 in. × 14 in., is varnished, eyeletted and strung. It gives useful information in regard to the method of packing carburising boxes, reheating, second reheating, hardening, quenching, etc., and it can be obtained free on application.

Business Notes and News

Electric Heat-treatment Furnace Demonstrations.

The Manchester Corporation Electricity Department have been having demonstrations at their workshop in Dickinson Road with the object of showing the application of electricity to industrial heating purposes. The equipment used has been supplied by Messrs. Wild-Barfield Electric Furnaces, Ltd., and many progressive manufacturers in this district have taken advantage of the invitation to supply work for treatment. The heat developed in these furnaces is under control to within two or three degrees, but in addition to accurate temperature control, the cleanliness and reduction of labour costs make the use of electricity an economical heating medium when all its advantages are considered.

One large furnace demonstrated was arranged for automatic control, to show its effectiveness for all-night service without attention. Another furnace indicated the use of the varying magnetic properties of steel at different temperatures for showing when steel is ready to be quenched. Demonstrations of this form are to be commended as they enable manufacturers to see the effect on their own products, and to calculate the cost of such an installation at their own works.

North-east Coast Institution of Engineers and Shipbuilders.

Andrew Laing Memorial Lecture.

The North-East Coast Institution of Engineers and Shipbuilders announce that the memory of the late Mr. Andrew Laing is to be perpetuated in the North-Eastern district by an annual memorial lecture, to be given under the auspices of this Institution. It will be remembered that Mr. Andrew Laing, who died on January 24, 1931, was the general manager and a director of the Wallsend Slipway and Engineering Co., Ltd., and under his guidance that company manufactured the engines of a large number of warships, cargo, and passenger ships, of which the Cunard Company's *Mauretania* is a prominent example.

It is very fitting that this memorial lecture should be directed to the advancement of the sciences of engineering and shipbuilding, a cause which formed a very large part of his own activities. It has been made possible, through the munificence of the Misses Jeannie and Catherine Laing, who, being desirous that a special fund should be founded to perpetuate the memory of their brother, have transferred into the name of the Institution the sum of £2,000, which is to be known as the Andrew Laing Memorial Fund, for the purposes of the lecture.

At an early date the Council of the Institution expect to be in a position to announce the first Andrew Laing memorial lecture. At the present time it may be stated that, in accordance with the terms of the trust deed, the lecture will be on the subject of engineering or shipbuilding, and each lecture will be given by the best intellect obtainable.

Institution Scholarship.—The Institution scholarship for 1931-2 has been awarded to Mr. Edward Joseph Charles Statham, an apprentice turner employed by the North-Eastern Marine Engineering Co., Ltd., Wallsend, aged 19. The scholarship is of the value of £100, and, subject to satisfactory reports on the scholar's work at the college at which he is studying, is tenable up to three years. Mr. Statham will study at Armstrong College.

A grant of £50 to assist him in continuing his studies at Armstrong College has been made to Mr. Thomas William Wilson, who was also a candidate for the 1931-2 scholarship. Mr. Wilson is aged 21, and is a junior draughtsman in the employment of Messrs. Richardsons, Westgarth and Co., Ltd., Hartlepool. A year ago he was selected by his company to receive the D. B. Morison Scholarship, which enabled him to attend Armstrong College for one year.

Mr. Will Pratt, the 1929 scholar, and Mr. Kenneth Fairbairn, the 1930 scholar, will also receive £100 each to enable them to continue their studies during the next twelve months.

George Mitchell Harroway Scholarship.—The George Mitchell Harroway scholarship, which is also administered by the Institution from funds generously donated by Mr. G. M. Harroway, of Blackwell Hill, Darlington, has been renewed.

The University of Sheffield.

During the past Session the work of the Department on Cold Working of Steel and other Ferrous Metals has been carried on by the Ironmongers' Company Research Fellow and the Ironmongers' Company Research Scholars in the laboratories of Metallurgy and of Engineering. The re-appointment of Mr. F. S. Merrils, as Research Fellow, and of Messrs. J. Dick and R. W. France, as Research Scholars for another year, is recommended. Mr. R. Goodacre, a University Scholar, has been engaged on work of the same kind, and during the next session, two University Scholarship holders, Mr. J. D. Urquhart and Mr. J. W. Rodgers, will be similarly available. Three programmes of research have dealt with the drawing of wire suitable for ropes and springs, the rolling of strip suitable for pressing, and the bright drawing of mild steel bars.

Wire Drawing.—The study of the drawing of wire has mainly taken the form of experiments to determine the best condition of drawing to obtain a high degree of resistance to fatigue. A special machine has been constructed, and this work will be continued.

An investigation of drawn wires for ropes disclosed unexpected variations in the hardness within the thickness of the wire, and it is hoped that further research will reveal the causes of some of the hitherto unexplained failures of wire ropes in service.

Rolling of Strip.—An investigation as to the amount of energy stored in cold-worked steel has occupied the entire time of one research worker, and will, it is hoped, be profitably continued. A report has been circulated among the manufacturers dealing with "stretcher strains" in deep pressings —which is one of the great difficulties with which the trade is faced—and it indicates a way to overcome the trouble.

Drawing of Bars.—Search is being made for the best form of dies for different section and qualities of steel. This is being done in conjunction with several important manufacturers, who have supplied their standard dies for the purpose. These reveal such a wide difference in design that the Department is making experiments to ascertain the most suitable type.

Resumption of Barrow Steelworks.

It is gratifying to note that the Barrow Steel Co. have resumed operations at their works after being idle for a number of months. Some months ago the stocks of iron carried by this firm were so great that it was necessary to stop production; during the last few weeks, however, the demand on these stocks has been such as to warrant them restarting two blast furnaces. The steel department, too, will be in operation, and the feeling generally, at these works, is more hopeful than for a long time past.

Manchester Association of Engineers.

A rather interesting meeting of the Manchester Association of Engineers took place on October 9, when the "Constantine" and "Butterworth" gold medals were presented. The former is an award made to the author of what is considered to be the most interesting and informative paper delivered at a meeting of the Association during a session, and on this occasion the honour was conferred upon Mr. F. W. Rowe, B.Sc., M.I.M.M., for his paper on "The Selection and Treatment of Gear Materials." The "Butterworth" medal is awarded to a member credited with the greatest number of contributions to discussions during a session, and Mr. J. S. G. Primrose, A.R.T.C., A.I.M.M., secured this honour.

Mr. C. E. Stromeyer, O.B.E., M.I.C.E., M.I.M.E., M.I.N.A., in a happy and thoughtful way, made the presentations, preparatory to delivering his presidential address, following which there was an interesting concert.

Messrs. Dorman Long to Supply Direct.

Messrs. Dorman Long and Co. have terminated their agency with Messrs. Alexander McBean and Son, of Wolverhampton, and in accordance with the company's policy of maintaining close and direct touch with all their customers, future sales of tramway rails and accessories will be conducted from the head office of the company at Zetland Road, Middlesbrough, with the assistance of the district offices at London, Birmingham, Manchester, Glasgow, Newcastle, and Belfast.

Some Contracts.

Davy Brothers, Ltd., of Park Ironworks, Sheffield, have just concluded important contracts with Arcos, Ltd., the representatives in this country of the Russian Government. In addition to the reconstruction of a 6,000-tons forging press, they are at present building one 10-ton, three 5-ton, and two 3-ton forging manipulators for new plants now being erected in Russia. Further orders for the same destination include a number of "Davy" patent turning gears, for rotating forgings whilst they are being forged under presses, as well as a 5-ton charging machine of the "Alliance" type.

Daniel Adamson and Co., Ltd., of Dukinfield, have obtained an order for a super-Lancashire boiler plant from the Hull Fish Meal and Oil Co., of Hull.

Peter Brotherhood, Ltd., Peterborough, has received orders for one 300-b.h.p. six-cylinder Brotherhood-Ricardo high-speed engine for oil-well drilling equipment in Burma, and for two 100 b.h.p. two-cylinder engines of the same type, one with Laurence-Scott dynamo, and one with Brotherhood dynamometer, for U.S.S.R., through Arcos, Ltd.

The Egyptian State Railways have awarded Messrs. Brown, Bayley's, of Sheffield, a contract for axles at a total price of £5,387, and Messrs. Hurst, Nelson and Co., of Motherwell, a contract for 10 bogie underframes (passenger).

Messrs. Clarke, Chapman and Co., Ltd., have announced another order for powdered-fuel equipment for a Japanese steamship. This is the second order booked in Japan during the last few weeks for this firm's Resolutor pulveriser equipment.

Newalls Insulation Co., Ltd., of Newcastle, has secured an order worth about £12,000 for the insulation of refrigerated spaces in the new Cunarder which is being built by Messrs. John Brown on the Clyde.

Parsons Marine Steam Turbine Co., Ltd., of Wallsend, have been awarded the contract for the complete propelling machinery for H.M. Cruiser *Neptune*, now building at Portsmouth Dockyard.

Base-plate Girder Casting for a 6,000 tons "Davy" Patent Forging Press being lowered on to a special railway carrier ready for transit to Hull en route for Russia. Weighing over 60 tons, this casting is one of a number for this press made at the Grimesthorpe Foundry of the English Steel Corporation Ltd.

McKie and Baxter, Ltd., Paisley, are stated to have received an order to supply a paddle steamer to their design and specification for river service abroad. The vessel will be 197 ft. in length, 29 ft. in breadth, and 7 ft. in depth, and will be fitted with surface-condensing machinery. The hull and machinery are to be erected and subsequently dismantled and shipped for re-erection at destination abroad.

Messrs. Pauling and Co., of 26, Victoria Street, S.W.1, have been awarding a contract by the Rhodesia Railways, Ltd., for the construction of a railway connecting Chambishi, situated approximately midway on the N'Kana-N'Changa branch, with Mufulira. This new line will be 19.7 miles in length and the route will follow closely the Chambishi-Mufulira Road.

Callender's Cable and Construction Co., Ltd., of Erith, have been awarded a contract by the India Store Department for the transmission-telephone system at Karachi.

Messrs. Davey, Paxman and Co., Colchester, have received several orders for Diesel engines. The Bank of England has ordered through its contractors, Drake and Gorham, London, four heavy duty engines; the Tenby Gas Consumers Co. one, and the Enniskillen Electric Light and Power Co. one. The Great Western Railway Co. have ordered two 45-kw. marine auxiliary sets with generators, and the Eagle Oil and Shipping Co. two propulsion engines with reverse gears.

The Birtley Iron Co., Ltd., have received a contract from Russia for a coal-cleaning plant. The plant will be the first of its kind to be installed in Russia.

Messrs. Workman, Clarke and Co., of Belfast, have received an order for a 7,000-ton vessel for the Standard Fruit and Steamship Corporation. The order is the first received since January, and a commencement will be made at once.

The Cleveland Bridge and Engineering Co., Ltd., of Darlington, have been awarded by the Sierra Leone Development Co., Ltd., the contract for two bridges, each consisting of three 100-ft. spans, together with cylinder foundations.

The Sentinel Wagon Works, Ltd., of Shrewsbury, have received a contract from the London and North-Eastern Railway Co. for a 100-h.p. double-geared shunting locomotive. This unit will be similar to other standard-type engines previously ordered from the same firm by the L.N.E.R.

The L.N.E.R. have placed a contract with the British Power Railway Signal Co., Ltd., for the resignalling of 30 miles of their main East Coast route tracks between York and Northallerton. The contract includes the supply and installation of the latest type of automatic and controlled searchlight and colour-light signals. Also included is an important power signalling installation at Thirsk.

Blackstone and Co., Stamford, have been awarded a contract for the supply of the machinery required for the Eastleigh and Bishopsgate sewerage scheme. The value of the contract is approximately £14,000.

The General Electric Company have been awarded what is claimed to be one of the largest contracts for telephone equipment yet placed. It covers the supply and installation in London of another 10,000-line "Director" type automatic exchange, together with tandem equipment for the automatic routing of inter-exchange calls in the West London area.

Titan Trackwork Company, Sheffield, have obtained an order from the Southern Railway for a large railway layout in manganese steel in connection with junction connections at London Bridge and Charing Cross stations.

Lectures on Refractories.

Lectures on "Refractories" are being given by Mr. Colin Presswood, B.A., F.G.S., at the College of Technology, Manchester, throughout the Session. The lectures commenced on October 8, 8-9 p.m., and will continue regularly throughout the Session on Thursday evenings.

A 500-k.w. WIRELESS VALVE.

A Remarkable Achievement.

In spite of rapid advances the wireless engineer has been gravely restricted in his efforts, economically and efficiently, to increase the power at his disposal by the fact that the thermionic valve, in its commercial form, has, up to the present, necessarily been constructed in the form of a highly evacuated glass bulb, into which are sealed permanently the electrodes necessary for its operation. The difficulties of construction and operation of this type of valve increased as greater outputs were required. Cooling, deterioration of the vacuum, and the great expense of replacement when the valve failed, all had presented difficult problems.

For many years the ideal of a valve whose vacuum would not become poorer with age, in which the great difficulty of sealing off the electrodes under vacuum in the process of manufacture would be avoided, and in which the filament could be replaced or other repairs executed, and the valve rapidly and easily again placed in operation, has been the object of much investigation.

Continuously evacuated valves have previously been operated successfully under laboratory conditions, the vacuum being maintained by means of the mercury-vapour pump. This process, however, was rendered commercially impracticable by the fact that the mercury vapour, due to its high vapour pressure, prevented the necessary degree of vacuum from being maintained unless recourse was had to the expensive and unwieldly process of cooling with liquid air.

The ideal for which previous investigators have striven—a demountable and continuously evacuated valve in a practical commercial form—has been achieved by Metropolitan-Vickers Electrical Co., a subsidiary of Associated Electrical Industries, Ltd. The discovery leading to this achievement emanated from the research laboratories of this company, wherein experiments led to the production of oil distillates having remarkable properties. They could be boiled at a fairly low pressure without decomposition, and yet at room temperature their rate of evaporation was so small that they could be placed inside a wireless valve without impairing the vacuum.

This proved to be an ideal liquid to replace the mercury of the vapour pump, as due to its low volatility, cooling could be effected with water and the cumbersome and expensive liquid-air process eliminated.

In 1930 a valve designed for an input of approximately 25 k.w. was constructed, incorporating the new development, and proved so satisfactory in operation, not only in the laboratory, but also in actual continuous service at the Rugby wireless station, that the G.P.O., which had from the early stages shown a lively and progressive interest in these tests, entrusted the Metropolitan-Vickers Electrical Co. with the design and manufacture of a 500-k.w. valve.

This new valve altogether weighs over a ton, and is built on a welded steel bedplate 8 ft. long by 3 ft. wide. Its water-cooled steel anode weighs 3 cwt., and is equipped with hydraulic jacks to facilitate demounting and assembly. Its filament current is approximately 500 amperes, and its filament emission 160 amperes. It is capable of operating the main transmitter at Rugby, thereby replacing a bank of 50 high-power valves.

No glass is used in its construction, but a robust combination of steel, porcelain, and copper, the most common materials utilised in the manufacture of electrical equipment. As a result of the continuous evacuation, and in sharp contract with valves of the permanently sealed type, this new valve improves with age, any gas evolved during its operation, and which in the sealed valve would inevitably impair the vacuum, being rapidly removed by the pumps. Thus an exceedingly high vacuum is maintained even at the highest power inputs. The pumps, with the exception of a simple type of primary extractor, have no moving parts, and mechanical trouble is therefore a very remote possibility.

The valve is completely demountable. In the event of filament or other repairs being necessary it may be rapidly taken to pieces, the repairs executed with ordinary engineering tools, and the whole re-assembled and placed back into operation in the course of a few hours. These new developments have made possible the manufacture of valves capable of dealing with inputs considerably higher than 500 k.w., and demountable continuously evacuated valves of many times this power—in itself several times that of what was previously the world's largest—are in no sense a visionary prospect.

IRON AND STEEL REPORT.

An almost immediate consequence of the gold standard decision last month was a stimulation of buying interest in the iron and steel markets, more especially in respect of foundry iron, and during the past three weeks operations have been more active than for some considerable time. One important effect of the new conditions has been to strengthen the position of British foundry irons as against Continental products in certain of the home markets, notably on the North-east Coast and in Scotland.

The actual demand for pig iron in virtually all centres has been better probably than on any previous occasion this year, and contracts have been freely entered into up to the end of December. Up to the present, however, although in several directions the situation at the consuming end has shown a slight improvement, and deliveries of foundry iron are consequently somewhat better in the aggregate than they have been, the growth of deliveries falls a long way behind what iron producers regard as satisfactory. Textile machinery manufacturers, to name only one branch, are not appreciably better off for work, and the same may be said of several other of the principal using industries. There is, however, at least one important branch where hopes of expanding trade run fairly high. Light castings makers have for some time been suffering in the home markets from Continental competition, and, where it has not already done so, the industry expects to benefit. Whether or not any advantage proves to be permanent will depend upon a continuance of the benefit, equivalent to a tariff of about 20%, which the departure from the gold standard is estimated to have conferred upon home manufacturers.

Meanwhile, it must be admitted that much the greater part of the business that has been done in pig iron has been in the nature of a precaution against a rising market. More than one user has been inquiring for supplies over the first quarter of next year, but makers have not been willing to book orders so far forward at the levels now current, and varying premiums have been indicated.

The position of the finished-iron branch is much the same as before. Crown bars have not been called for any more freely than before, and the cheaper qualities for the nut, bolt, and fencing industries have also not fared any better. There has, however, been rather more interest displayed in hoops, strip, and several other iron products. Values are firm without being altered, compared with recent levels.

With certain stipulations as to the tonnage to be taken, British steel makers have renewed their grant to shipbuilders in this country, but the demand for plates and other steel materials from this direction continues at a level which is much below normal. Apart from odd exceptions, constructional engineers, more especially, perhaps, in the North, are poorly situated, and in neither case has much forward buying been experienced. The locomotive building industry is another outlet for steel which has been, and continues to be, decidedly smaller than it was a year ago. Rising quotations for special alloy steels have, however, stimulated buying interest, and the past few weeks have witnessed a fair flow of orders for these for delivery a month or two ahead. In the case of bright drawing bars and one or two other lines, the demand has been on a better scale. Small rerolled bars have been advanced by about 10s. a ton, but boiler plates at £8 15s. are not too strong, while values of most other descriptions of steel have been maintained.

A striking result of the changed financial situation was the temporary withdrawal from British markets of quotations for Continental products. Inquiry for these developed to some extent, but the position of affairs was complicated, and it is only recently that Continental sellers have resumed quoting, the rates representing an increase of up to 25% above the old levels. On this basis a number of orders for finished products have been reported.

MARKET PRICES

ALUMINIUM.

99% Purity	£95 0 0

ANTIMONY.

English	£40 0 0
Chinese	25 0 0
Crude	20 0 0

BRASS.

Solid Drawn Tubes	lb.	9¾d.
Brazed Tubes	lb.	11¾d.
Rods Drawn	,,	8¾d.
Wire	,,	8⅛d.
*Extruded Brass Bars	,,	4⅝d.

COPPER.

Standard Cash		£37 16 3
Electrolytic		41 0 0
Best Selected		36 5 0
Tough		35 15 0
Sheets		75 0 0
Wire Bars		41 0 0
Ingot Bars		41 0 0
Solid Drawn Tubes	lb.	10¾d.
Brazed Tubes	,,	10¾d.

FERRO ALLOYS.

‡Tungsten Metal Powder	lb.	0 1 11½ Plus 20%
‡Ferro Tungsten	,,	0 1 8½ Plus 20%
Ferro Chrome, 60-70% Chr. Basis 60% Chr. 2-ton lots or up.		
NOMINAL: 2-4% Carbon, scale 12/- per unit	ton	33 2 6
NOMINAL: 4-6% Carbon, scale 8/- per unit	,,	25 0 0
NOMINAL: 6-8% Carbon, scale 8/- per unit	,,	24 0 0
NOMINAL: 8-10% Carbon, scale 8/- per unit	,,	23 15 0
§Ferro Chrome, Specially Refined, broken in small pieces for Crucible Steelwork. Quantities of 1 ton or over. Basis 60% Ch. Guar. max. 2% Carbon, scale 11/6 per unit	,,	36 0 0
Guar. max. 1% Carbon, scale 15/- per unit	,,	39 17 6
§Guar. max. 0.7% Carbon, scale 15/- per unit	,,	40 10 0
‡Manganese Metal 96-98% Mn.	lb.	0 1 6
‡Metallic Chromium	,,	0 2 9
§Ferro-Vanadium 25-50%	,,	0 12 8
§Spiegel, 18-20%	ton	6 17 6
Ferro Silicon—		
Basis 10%, scale 3/- per unit	ton	6 0 0
20/30% basis 25%, scale 3/6 per unit	,,	7 15 0
45/50% basis 45%, scale 5/- per unit	,,	10 17 6
70/80% basis 75%, scale 7/- per unit	,,	16 8 6
90/95% basis 90%, scale 10/- per unit	,,	25 0 0
§Silico Manganese 65/75% Mn., basis 65% Mn.	,,	12 7 6
§Ferro-Carbon Titanium, 15/18% Ti	lb.	0 0 6
Ferro Phosphorus, 20-25%	ton	17 10 0

FUELS.

Foundry Coke—	
S. Wales Export	£1 2 0 to £1 16 6
Sheffield Export	0 14 0 to 0 15 0
Durham Export	1 4 0
Furnace Coke—	
Sheffield Export	0 14 0 to 0 15 0
S. Wales ,,	0 16 6 to 0 17 6
Durham	0 13 0

GUN METAL.

*Admiralty Gunmetal Ingots (88 : 10 : 2)		£51 0 0
*Commercial Ingots		43 0 0
*Gunmetal Bars, Tank brand, 1 in. dia. and upwards	lb.	0 0 10
*Cored Bars	,,	0 0 11

LEAD.

Soft Foreign	£12 15 0
English	14 5 0

MANUFACTURED IRON.

Scotland—	
Crown Bars	£10 5 0
N.E. Coast—	
Rivets	11 5 0
Best Bars	11 0 0
Common Bars	10 10 0
Lancashire—	
Crown Bars	9 15 0
Hoops	12 0 0
Midlands—	
Crown Bars	£9 5 0 to 10 7 6
Marked Bars	12 0 0
Unmarked Bars	—
Nut and Bolt Bars	£8 10 0 to 9 0 0
Gas Strip	10 12 6
S. Yorks.—	
Best Bars	10 15 0
Hoops	12 0 0

PHOSPHOR BRONZE.

*Bars, " Tank " brand, 1 in. dia. and upwards	lb.	9d.
*Cored Bars	,,	11d.
†Strip	,,	10¾d.
†Sheet to 10 W.G.	,,	11¼d.
†Wire	,,	12⅜d.
†Rods	,,	11¼d.
†Tubes	,,	1/4¾
†Castings	,,	1/1

†10% Phos. Cop. £30 above B.S.
†15% Phos. Cop. £35 above B.S.
†Phos. Tin (5%) £30 above English Ingots.

PIG IRON.

Scotland—	
Hematite M/Nos.	£3 8 6
Foundry No. 1	3 12 0
,, No. 3	3 9 6
N.E. Coast—	
Hematite No. 1	3 5 6
Foundry No. 1	3 1 0
,, No. 3	2 18 6
,, No. 4	2 17 6
Cleveland—	
Foundry No. 3	3 7 0
,, No. 4	2 17 6
Silicon Iron	3 1 0
Forge No. 4	2 17 0
N.W. Coast—	
Hematite	3 14 6
Midlands—	
N. Staffs Forge No. 4	3 1 0
,, Foundry No. 3	3 7 0
Northants—	
Forge No. 4	2 18 6
Foundry No. 3	3 5 6
Derbyshire Forge	3 2 0
,, Foundry No. 3	3 7 0
West Coast Hematite	4 3 6
East ,, ,,	3 17 0

SWEDISH CHARCOAL IRON AND STEEL.

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S. Wales	£2 0 0 to 2 5 0
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Cleveland	1 5 0
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,, ,, (Marine) ,,	10 10 0
,, ,, (Land), N.E. Coast	10 0 0
,, ,, (Marine) ,,	10 10 0
Angles, Scotland	8 7 6
,, North-East Coast	8 7 6
,, Midlands	8 7 6
Joists	8 15 0
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Fishplates	12 0 0
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Hoops	£9 0 0 to 10 0 0
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Round and Squares, ½ in. to ¼ in.	,,	3d.
Under ¼in. to 3/16 in.	,,	1/-
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,, ,, ½ in. × ¼ in.	,,	1/-

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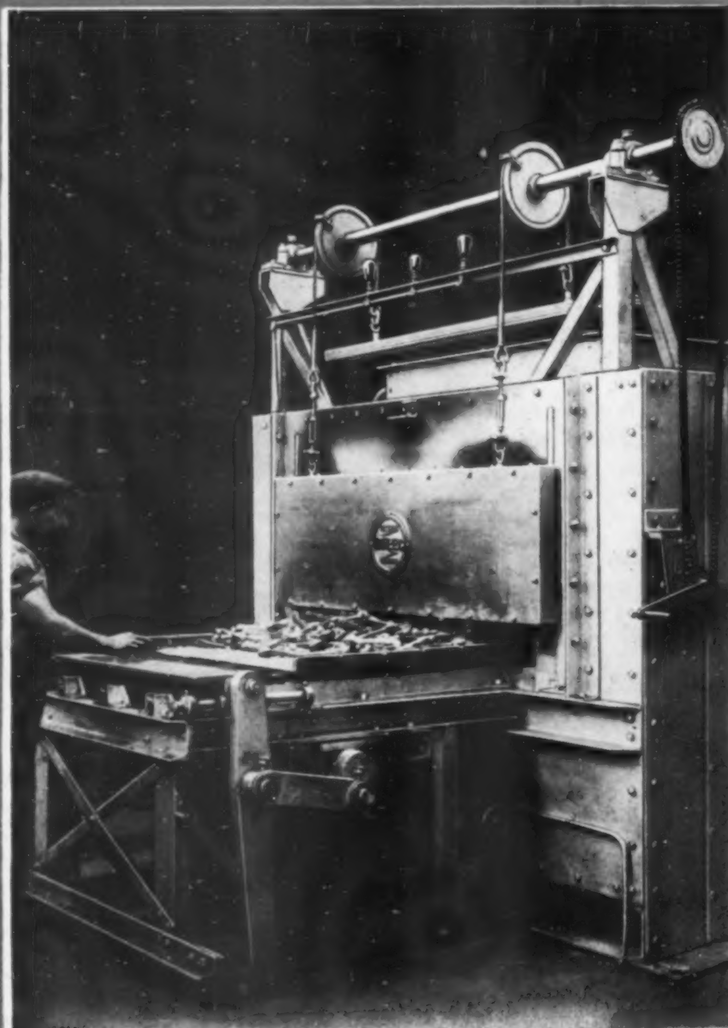
Bureau of Standards
JUN 1 1931

METALLURGIA

THE BRITISH JOURNAL OF METALS.

THE ELECTRIC FURNACE

BIRLEC



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Effect of Molybdenum

DURING recent years the use of molybdenum in steel has developed at a rapid rate. The increasing use of this alloying element is not due to any distinctive cleansing or deoxidising effect, as molybdenum acts as an alloy only, but to the important qualities it imparts to a steel when alloyed in suitable proportion.

Chemical and microscopical examination have shown that molybdenum dissolves in the ferrite, and that it combines with the carbon in the steel, forming strong grained carbides which are retained in solid solution on cooling through the critical ranges. Considerable research work has been carried out on steels containing molybdenum, and the results of many investigations indicate that additions in proper proportions to standard analyses, followed by suitable heat-treatment, tends to improve the standard quality by increasing the ductility and toughness for a given elastic limit, or for a given ductility the elastic limit and toughness are increased, improves the machining quality, gives greater depth hardening, and a higher ratio of elastic limit to tensile strength.

In addition, it is claimed the tendency for scale to adhere in forging and stamping is considerably reduced when molybdenum is present, cleaner forgings thus being produced; further, it is not lost through oxidation when added to molten metal, and is fully recovered on remelting of scrap.

TEMPER BRITTLENESS.

Tests also indicate that the introduction of molybdenum serves to eliminate temper brittleness, which is so characteristic of many alloy steels. This is important when it is advisable to avoid the risk of internal stresses and distortion of parts, particularly with wide variation in section of metal. In such instances the ideal steel is that which will pass the necessary tests for strength, ductility, and impact when cooled slowly from a tempering heat without quenching. Only small percentages of molybdenum are necessary for this purpose. Thus, in the case of steels developing temper brittleness to a marked extent, the addition of 0.3 to 0.4% will practically eliminate the tendency, while increased amounts not exceeding 0.6% will render the steel non-temper brittle. In this way molybdenum imparts qualities to the steel which enable it to retain a high impact value irrespective of the rate of cooling from the tempering heat.

MOLYBDENUM-CARBON STEELS.

Although molybdenum improves the physical qualities of straight carbon steels it is used chiefly in combination with other alloying elements, such as chromium, nickel, vanadium, etc., when it has the effect of intensifying the beneficial properties of these elements, and which, in turn, have the effect of assisting molybdenum to exercise its own special functions. While the demand for molybdenum-carbon steels is so far not great, some manufacturers have found these steels, in sheet form, suitable for deep-drawing purposes. This type of steel is also being developed for castings. A comparison between the properties of a 0.3% carbon steel and a similar steel with the addition of 0.31% molybdenum is as follows:—

	Tensile Strength Tons per Sq. In.	Yield Point Tons per Sq. In.	Elongation % in 2 in.	Reduction of Area %
Carbon Steel	34	21	38	68
Molybdenum-Carbon	41	32	42	70

MOLYBDENUM-CHROMIUM STEELS.

The addition of molybdenum to the chromium steels represents an important range of engineering steels. The physical properties of molybdenum-chromium steels are much greater than are obtainable from plain carbon steels and many alloy steels. They may be used for casehardening purposes, but the temperature limits between which satisfactory results can be obtained are very narrow. For heat-treated forgings, however, the ranges of hardening temperatures are wide, and these steels give great strength and toughness. The increased properties imparted to a chromium steel are shown in the following comparison:—

Steel. C.	Cr.	Mo.	Tensile Strength Tons per Sq. In.	Yield Point Tons per Sq. In.	Elongation % in 2 in.	Reduction of Area %
0.28	0.99	—	62	57	17	58
0.26	0.76	0.31	68	64	19	62

on the Physical Qualities of

Apart from the increased properties obtained in these steels, they possess the property of being readily machinable even when hardened and tempered to give a very high tensile. In the annealed condition they may be softened to a condition approaching a medium carbon steel. This property of ease of machining, either treated or untreated, makes their use particularly attractive to the automobile industry.

Molybdenum-chromium steels are being increasingly used for tubing in welded structures, particularly in connection with aeroplane construction, where extra strength is required. Comparative tests with a molybdenum-chromium steel containing 0.3% carbon, 1% chromium, and 0.2% molybdenum have shown many advantages over plain carbon steels, particularly in regard to butt weld and alternating tests.

MOLYBDENUM-MANGANESE STEELS.

These steels are used for constructional purposes where an alloy steel is required, but where expense does not permit the use of the more commonly accepted alloy steels, they are used for parts of light to medium section and can be readily forged and heat-treated without requiring any special care.

Casehardening steels of molybdenum manganese are also manufactured.

The addition of molybedenum improves strength and toughness.

MOLYBDENUM-NICKEL STEELS.

The molybdenum nickel steels give very satisfactory results when used for casehardening work.

They are claimed to require only a single quench after carbonising to develop higher physical properties than those obtained by steels requiring a double quench.

A suitable molybdenum nickel steel intended primarily for casehardening work, has a composition consisting of 0.15% carbon, 0.30% molybdenum, and 1.25 to 1.90% nickel.

Molybdenum-nickel steel was developed in an endeavour to produce a steel having higher and more uniform properties suitable for light armour-plating, and of better machinability than the chromium-nickel and 5% nickel steels. Experiments led to the addition of molybdenum to a 5% nickel steel having low manganese, silicon, sulphur, and phosphorus contents.

In comparison with nickel steel the addition of molybdenum imparts the following properties :—

Steel. C.	Ni.	Mo.	Tensile Strength Tons per Sq. In.	Yield Point Tons per Sq. In.	Elongation % in 2 in.	Reduction of Area %
0.29	4.52	—	42	32	27	62
0.26	4.56	0.51	54	46	27	60

MOLYBDENUM-CHROMIUM-NICKEL STEELS.

An unusual combination of properties is presented in this range of steels, as in addition to improvement in their resistance to stresses they are responsive to ordinary heat-treatment methods and have better machinability. The range embraces the following :—

Carbon.	Molybdenum.	Chromium.	Nickel.
0.25—0.35	0.3—0.6	0.7—1.1	1.75—3.25

Some excellent physical properties have been obtained after heat-treatment in both rolled and cast steels, and comparison between low and high nickel-chromium steels and similar steels having molybdenum added to the compositions indicate the improvement imparted. Thus :—

Steel. C.	Ni.	Cr.	Mo.	Tensile Strength Tons per Sq. In.	Yield Point Tons per Sq. In.	Elongation % in 2 in.	Reduction of Area %
0.36	1.8	1.0	—	50	40	26	66
0.34	1.78	1.08	0.61	62	54	24	65
0.29	3.20	0.81	—	60	52	19	59
0.26	3.0	0.8	0.44	65	58	21	67

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64	..	19	..	62

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0.26	4.56	0.51	.. ..	54	..	46	..	27

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0.36	1.8	1.0	—	..	50	..	40	..	26
0.34	1.78	1.08	0.61	..	62	..	54	..	24
0.29	3.20	0.81	—	..	60	..	52	..	19
0.26	3.0	0.8	0.44	..	65	..	58	..	21

l Qualities of Various Steels.

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longation % in 2 in.	Reduction of Area %
27	62
27	60

TEELS.

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Nickel.
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sitions indicate the

longation % in 2 in.	Reduction of Area %
26	66
24	65
19	59
21	67

MOLYBDENUM-CHROMIUM-VANADIUM STEELS.

The addition of molybdenum to chromium-vanadium steels has been investigated, and the results indicate that they either improve ductility for similar strength or give greater strength with similar ductility, according to the percentage added. A comparison showing the properties of a chromium-vanadium steel and a similar steel with added molybdenum is as follows :—

Composition. C.	Cr.	V.	Mo.	Tensile Strength Tons per Sq. In.	Yiled Point Tons per Sq. In.	Elongation % in 2 in.	Reduction of Area %
0.39	1.08	0.17	—	75	67	20	55
0.39	1.05	0.17	0.81	85	78	19.5	59

HEAT-TREATMENT.

To obtain the best results with molybdenum steels, heat-treatment is required to bring out the influence of the molybdenum. Every 0.1% molybdenum raises the Ac point 5 to 8 deg. C., balancing, to some extent the action of nickel and carbon. Wide ranges of hardening temperatures are available, however, without causing an appreciable difference in the physical properties. Thus, in the case of a molybdenum-chromium steel having the following composition :—

Carbon.	Molybdenum.	Chromium.	Manganese.
0.27	0.42	0.83	0.66

comparatively small differences were obtained from tests made when hardened at various temperatures. Tests were made on ⅞-in. bars, which were treated and water-quenched at the temperatures given in the accompanying table, the bars being subsequently tempered by heating to 560° C., and allowed to cool slowly in the furnace.

Hardened °C.	Yield Point Tons per Sq. In.	Tensile Strength Tons per Sq. In.	Elongation % in 2 in.	Reduction of Area %	Brinell Hardness Nos.	Izod Ft.-Lb.
820	62.5	72.5	18.5	62.7	319	58
870	62.0	72.0	17.0	63.1	321	62
930	61.5	71.5	17.5	61.7	321	60
980	61.5	70.5	18.0	61.5	319	61
1,040	62.0	71.0	16.8	57.9	317	66
1,090	62.0	70.0	17.0	59.0	317	55

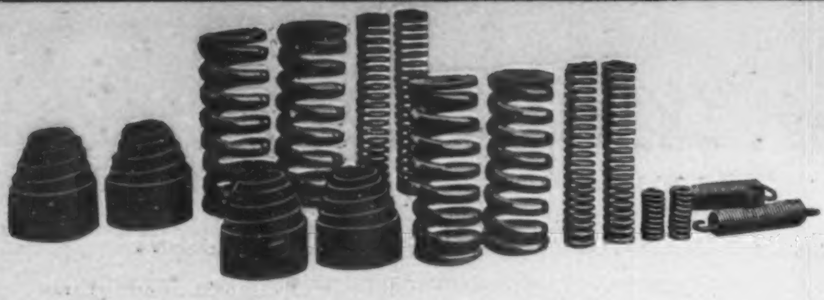
In order to obtain the desired strength molybdenum steels should be held for a longer time at the appropriate tempering temperature than other alloy steels. This has the effect of relieving hardening stresses and assists the molybdenum to give the steel its high quality.

MOLYBDENUM TOOL STEELS.

Molybdenum acts in a manner resembling tungsten, but differs from it in some basic characteristics. Molybdenum is a carbide former, and affects the critical points of the steel in a manner similar to tungsten, but when present in proportions greater than 3 or 4% special precautions are needed to prevent it volatilising from the steel at rolling and forging temperatures. This characteristic has prevented its wider application in tool steels, but it has been overcome recently by using enough borax to cover the heated steel with a thin layer which prevents contact with the air.

Certain high-speed steels with 8% molybdenum have had the demolybdenised zone worked and machined off, and the steel has shown cutting efficiency comparable with 18% tungsten steels, but with the advantage of increased toughness. Such steels, however, have not been practical to manufacture. The majority of molybdenum used in tool steels is associated with high-speed steels, in which it is used up to 2% to displace tungsten. An improved high-speed steel was patented in 1919 in which about 6% molybdenum was substituted for 4% chromium and 20% tungsten. In addition to molybdenum the alloy contained about 1% vanadium, which appears to stabilise the properties of the molybdenum steel.

"Metallurgia" Chart, May, 1931.
The Kennedy Press, Ltd., Kennedy House,
Liverpool Road, Manchester.



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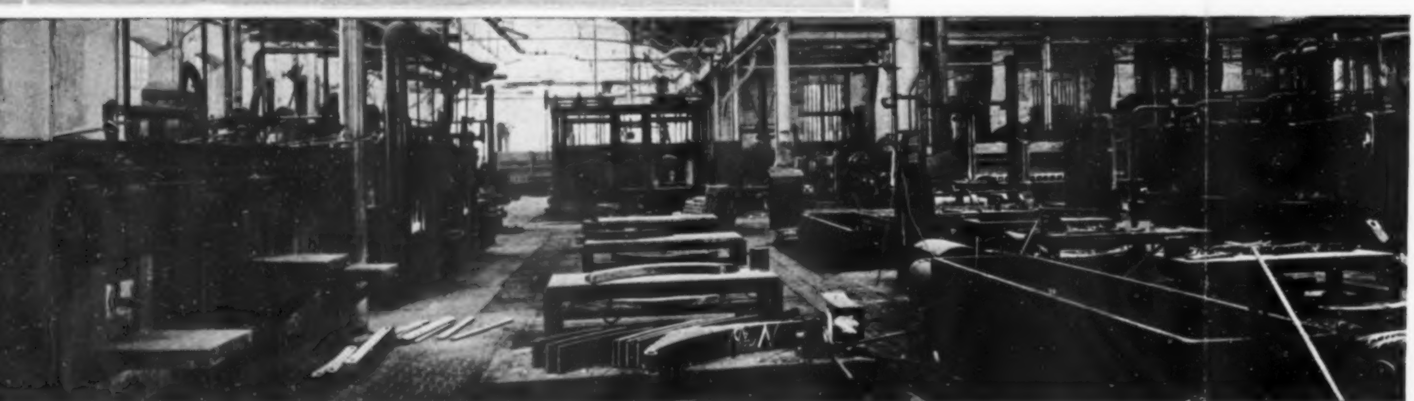
The "Revergen" astounds by its fuel economy!



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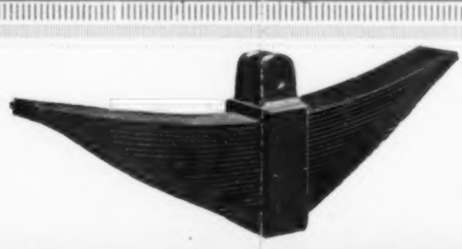
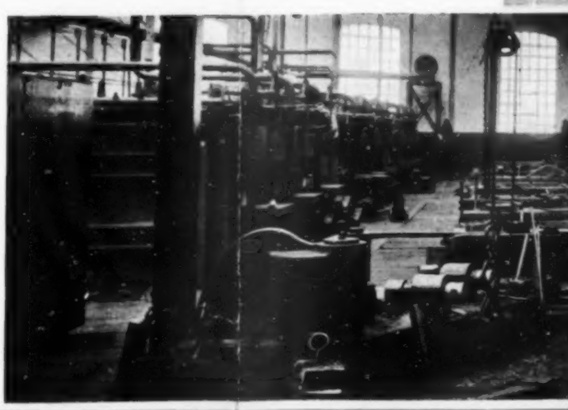
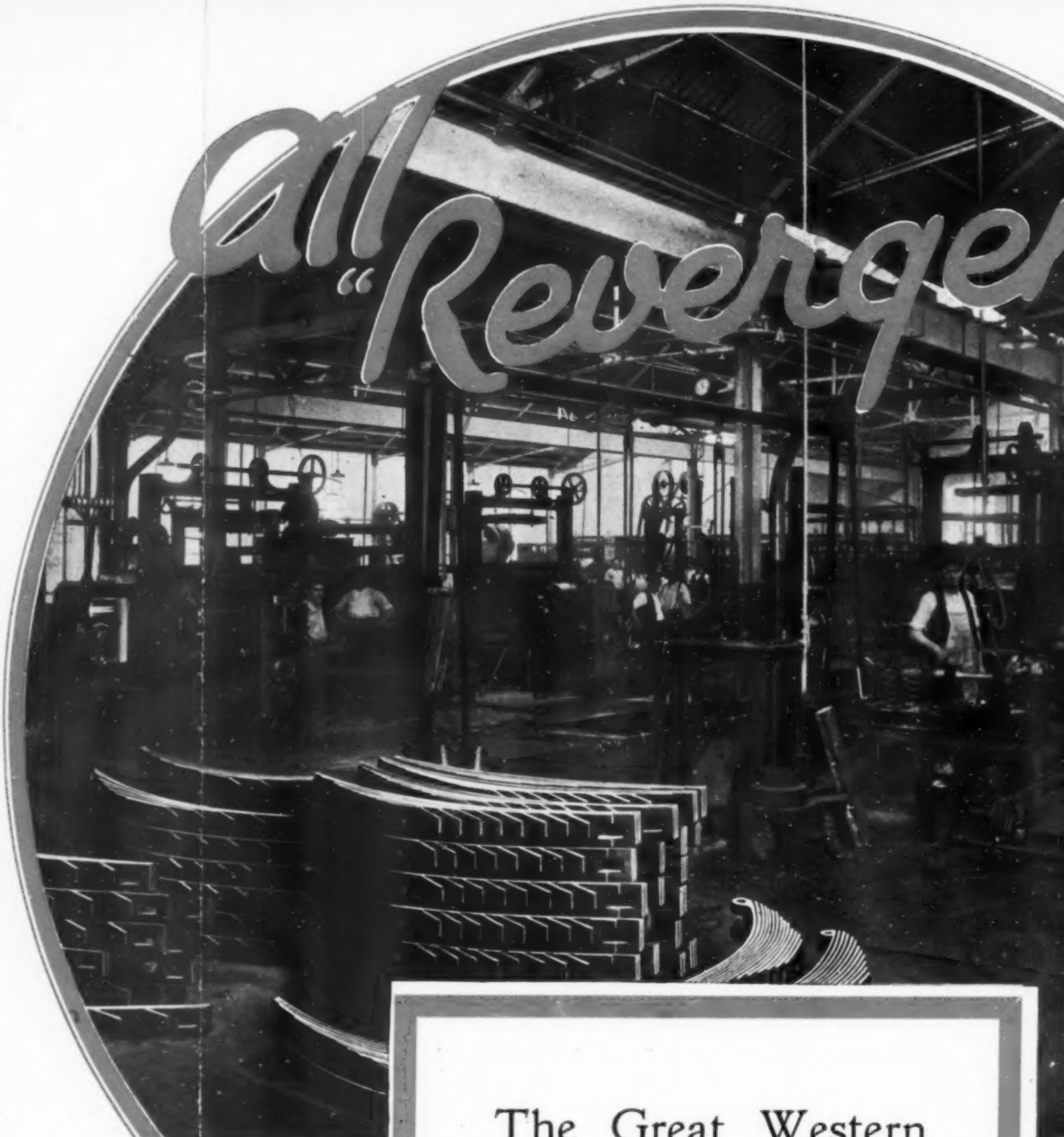


The Great Western Railway Company's Spring Works at Swindon are equipped throughout with Davis "Revergen" Gas-fired Furnaces.





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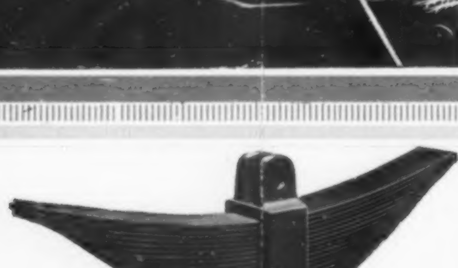
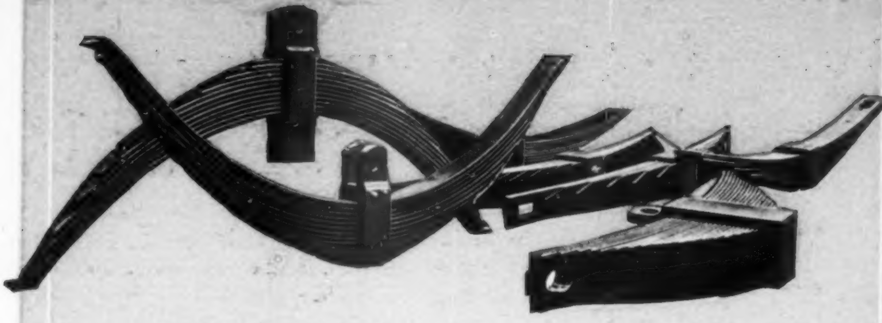
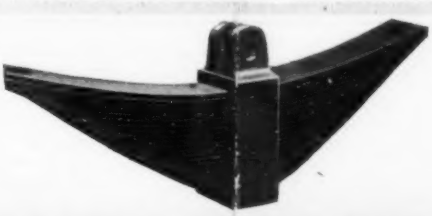




EFFICIENCY is of such outstanding importance to Railway Engineers that the Great Western Railway Company, as a result of their experience with the "**Revergen**" Furnace, have now installed no less than 30 furnaces, used for practically every heat treatment operation to which metal is subjected in the production of parts for railway rolling stock.

The repeat orders received from the Great Western Railway Company are in themselves the highest possible testimony that can be given to the efficiency of the "**Revergen**" Furnace.

There is no other furnace obtainable capable of giving the same high Efficiency combined with Quality of Product and Maximum Fuel Economy as the "**Revergen.**"



DIAMOND FOUNDRY
LUTON, BEDS.

Vol. 4.—No. 20. JUNE, 1931. Price 2/-. [Subscription 24/- per annum, post free]
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JUN 2 9 1930

METALLURGIA

THE BRITISH JOURNAL OF METALS.

WORM GEARS.

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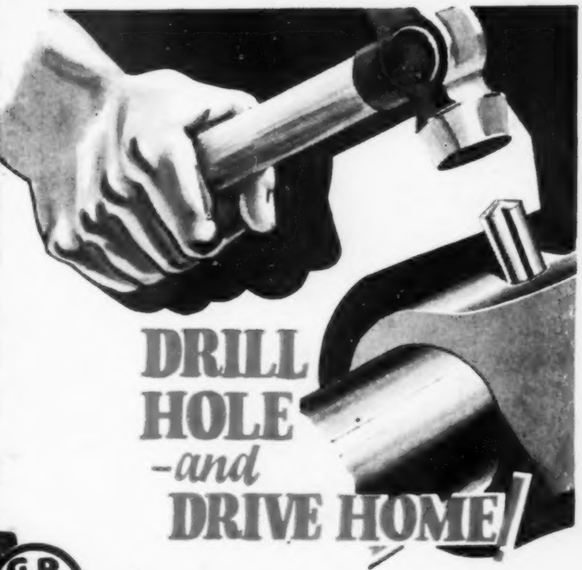
RED BANK - - MANCHESTER.



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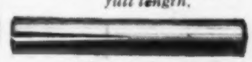
G.P. 2.
With tapering groove half length.

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PULVERISED COAL FIRED

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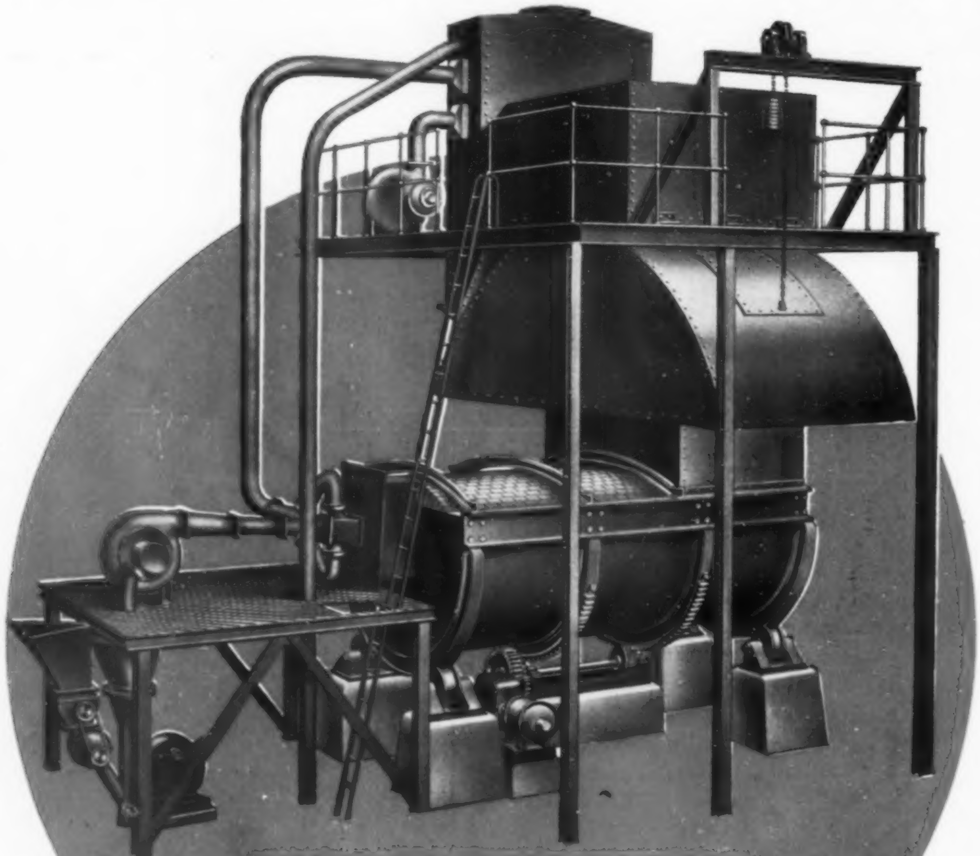

Our many friends who are familiar with the "SKLENAR" furnace as a highly economical melting unit for Non-ferrous Metals will be interested in this new "Sklenar," which after patient tests and research we now offer for high duty White and Grey Irons.

The furnace is fired by Pulverised Coal with a rocking action, giving perfect metal agitation and heat distribution, a long refractory life, and provides :—

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The Surface Treatme

Principles and Classification o

THE constantly growing field of technical applications of aluminium and its alloys has made it increasingly necessary to be able to vary the surface, to provide for such requirements as decoration, protection from chemical, physical, and mechanical action, electric insulation, the formation of metal connections, and absorption of heat; or combinations of these requirements. Some valuable information on this subject has recently been issued by the British Aluminium Co., Ltd., in which the available methods of surface treatment are classified and which form the basis of these particulars.

Decorative surface treatment has made great advances. Metal objects generally can receive to-day at the manufacturer's hands, quite apart from the craftsman's or artist's work, as great a range of colour and decorative effects as those in any other media. Aluminium, especially, has had a large amount of attention directed towards its more delicate decoration. In the constructional trades, further, a general demand has arisen within the last few years for aluminium parts to be colour-matched to adjacent non-aluminium parts.

Protection offers a much bigger problem to surface treatment of aluminium, whose characteristic properties are such as to make many of the usual methods either difficult or impossible to apply. With regard to protection from mechanical injury, from the point of view of surface treatment this is largely confined to reduction of frictional wear. In this connection two interesting examples are the use of zinc plating to prevent aluminium parts from seizing, and the recent introduction of a soft rubber surface coating to reduce abrasion. Protection from physical injury is again, from the point of view of surface treatment, limited in practice to providing a surface relatively indifferent to temperature changes. For high-temperature resistance the oxidation processes provide a satisfactory solution for aluminium. The question of protection from chemical effect, or corrosion, is by far the greatest problem with which protective surface treatment is called upon to deal.

METHODS OF SURFACE TREATMENT.

The available methods of surface treatment may be divided broadly into two main categories, according to whether they depend ultimately on chemical or mechanical means. The following classification shows the principal applications of the different processes :—

MECHANICAL ...	Pressure plating	Protection.
	Polishing	Decoration.
	Spray coating	Decoration.
	Painting	Decoration or protection.
	Ornamental finishing—scratch brushing	Decoration.
	,, ,, curling	Decoration.
CHEMICAL : (a) Pure chemical	Ornamental finishing—matting or frosting	Decoration.
	Immersion processes—colouring	Decoration.
	,, ,, metal plating	Protection.
	,, ,, oxidising	Protection.
	,, ,, miscellaneous	Protection.
(b) Physico-chemical ...	Diffusion processes	Protection.
	Cementation	Protection.
	Oxidation by Heating	Protection or insulation.
(c) Electro-chemical ...	Anodic oxidation	Protection or insulation.
	Electro deposition—metal plating	Protection or insulation.
	,, ,, vulcanising	Protection.
	,, ,, colouring	Decoration.
	,, ,, coppering	Forming metal connections.
	,, ,, blackening	Heat absorption or radiation.
	,, ,, miscellaneous.	

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[1] A. Passalacqua. E.P.

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ion of Mechanical and Chemical Methods of Surface Treatment

DISTINGUISHING ALUMINIUM FROM OTHER METALS

differences distinguish aluminium from other metals where surface concerned. Its mechanical qualities, which allow of obtaining a smoother most metals, especially ferrous metals, are advantageous in mechanical ment. Its chemical properties, outstandingly its extreme oxidisability, its in the electromotive scale and its high reactivity, on the other hand, place lvantage for all processes involving chemical reaction ; these difficulties vercome by special methods applicable to the class of phenomena entering ticular process.

to all methods of surface treatment is the necessity for a *clean initial*. In the case of aluminium this is a difficult problem on account of reactivity referred to, and has resulted in much research.

ral method of pre-cleaning depends on, first, a degreasing of the surface nic solvent ; and, second, an attempt at oxide removal by both alkali and for which a vast number of formulæ exist. For pure aluminium, chiefly r mixtures containing the latter or solutions of sodium salts are used ; ial aluminium and alloys HNO_3 is generally used. In many cases, thods special to the post-treatment are prescribed.

IANICAL METHODS OF SURFACE TREATMENT.

E PLATING.—An English patent[1] was taken out in 1924 to cover a process ılly coating aluminium with a heavy metal, such as copper, lead, silver, The process consisted in heating the aluminium, cleaning the surface compounds, continuing the heating to 300°—550° C., spreading the layer h as tin on the face of the aluminium, and pressing on a thin cleaned sheet metal, using hydraulic pressure, and cooling under pressure.

nical process is also made use of in the German Allautal and Duralplat rican Alclad alloys, the high-tensile strength alloys Lautal and Duralumin by a special pressure process with a considerable plate of pure aluminium s the alloys corrosion resistant.

G.—Polishing is rather more difficult in the case of aluminium than in her metals, on account principally of its softness ; softer polishing wheels to prevent the metal surface being dragged out and the wheel becoming ner abrasives are necessary. The high thermic conductivity and specific lisadvantages, particularly as the coefficient of friction is also high, and the ed by rubbing is, therefore, transmitted rapidly through the articles, ing difficult. There is also the risk of the polishing wheel burning. The favour of aluminium for polishing is its lightness, which facilitates

nique of polishing to give a high mirror-like polish involves three stages ary cleaning—smoothing down the surface (more especially in the case gs), buffing, and rubbing up with a polishing paste. The surface smoothing ed with coarse-grained files or emery wheels, the surface being kept ıbricated. Buffing is carried out with soft buffing wheels of chromed ag, or calico, using some abrasive powder mixed with a lubricating grease. bing-up is done with a suitable metal polishing paste such as " Almin."

COATING (SCHOOP PROCESS).—Spray coating or " metallisation " of usually confined to galvanising or coppering, the former either for sons or as a preliminary to gilding or plating with other metals, the latter purposes. The zinc or copper is applied with a Schoop " metal pistol " ; metal is automatically fed through the pistol body into the nozzle, where it meets the hot zone of an oxy-b compressed air ; the metal, as soon high velocity against the surface o and sandblasted).

PAINTING AND ENAMELLING.—The is probably more important for de research has been carried out on th which renders light metals comple however, claimed that certain var ordinary protection ; and that bitu by sea water.

The characteristic mechanical the difficulties encountered in painti metals making a higher elasticity problem of adhesion more difficult. of paint to the slower-drying oil pai cellulose paints and rapid-drying oil resolves into a question of the co painting oxide treatment is usually is thereby attainable. For decorat by treating with soda solution, and hot water. Sandpapering must not be sand-blasted or smoothed with e on the market for light metals pre and require that alkaline cleansing

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[1] a. E.P. 209,063 (1924).

Surface Treatment of Alumin

Principles and Classification of Mechanical and Chemical Methods

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FEATURES DISTINGUISHING ALUMINIUM FROM OTHER

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The technique of polishing to give a high mirror-like polish involves thr after preliminary cleaning—smoothing down the surface (more especially in of sand-castings), buffing, and rubbing up with a polishing paste. The surface s is accomplished with coarse-grained files or emery wheels, the surface be thoroughly lubricated. Buffing is carried out with soft buffing wheels of leather, felt, rag, or calico, using some abrasive powder mixed with a lubricatin The final rubbing-up is done with a suitable metal polishing paste such as "

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it meets the hot zone of an oxy-blowpipe flame which is surrounded by a cone of compressed air; the metal, as soon as it becomes molten, is atomised and forced at high velocity against the surface of the aluminium (which is, as usual, pre-cleaned and sandblasted).

PAINTING AND ENAMELLING.—The painting of aluminium, contrary to other metals, is probably more important for decoration than for protection, for although much research has been carried out on the subject, no paint medium has been found so far which renders light metals completely resistant to corrosion. Some workers have, however, claimed that certain varnishes and nitrocellulose paints afford complete ordinary protection; and that bituminous paints afford protection against corrosion by sea water.

The characteristic mechanical properties of the light metals also contribute to the difficulties encountered in painting, the higher expansion and contraction of these metals making a higher elasticity of the paint coating necessary, and rendering the problem of adhesion more difficult. The former property practically limits the choice of paint to the slower-drying oil paints (although good results have been claimed with cellulose paints and rapid-drying oil paints by using a smoother). The latter problem resolves into a question of the control of the preparatory surface. For protective painting oxide treatment is usually given preliminarily and good adhesion of the paint is thereby attainable. For decorative painting the surface must be rendered matt by treating with soda solution, and subsequently washing with concentrated acid and hot water. Sandpapering must not be done. For castings, however, the surface should be sand-blasted or smoothed with emery before matting. Many of the special paints on the market for light metals prescribe special cleansing solutions (usually organic) and require that alkaline cleansing liquids shall not be used.

The usual process of enamelling is to employ one coat of primer, one or two coats of coloured enamel, and one or two finishing coats, applied either by spraying, brushing, or dipping—spraying giving the most durable result. The coats should be applied thinly and given full time to dry—this is important.

Typical primers are a 3 : 1 mixture of turpentine and linseed oil, or a 3 : 1 mixture of raw linseed oil and quick-drying varnish. Ground paints containing zinc salts or red oxide are also used; two such are made up of 300 parts zinc chromate, 225 parts raw linseed oil, 50 parts turpentine, 15 parts cobalt drier; or 40 parts neutral red oxide, 20 parts zinc chromate, 30 parts linseed oil varnish, 8 parts turpentine, and 2 parts Japan drier.

The enamels most commonly used are cellulose enamels. There are also a large number of proprietary lacquer paints specially produced for light metals—"Glyptal" (phtalic anhydride with glycerine thinned with 50/50 toluol and naphtha), "Inertol," "Tokiol," etc.

Two interesting developments in the technique of painting light metals have recently been investigated. Drying has been accelerated by the use of ultra-violet light; and researches have been carried out on combining heat-treatment of light alloys with drying of the paint.

ORNAMENTAL FINISHING—SCRATCH BRUSHING.—A fine satin finish is given to aluminium by a scratch brush running at 1,400 r.p.m., the wheel being run dry and a little lime being used on the wires occasionally to keep them free from oil or grease.

ORNAMENTAL FINISHING—CURLING.—This method, which consists in rubbing the surface over in circles with a cork or tool covered with leather and coated with fine emery, gives a pseudo "engine-turned" surface. The work can be carried out by hand or using a lathe, and different effects can be obtained by making the circles overlap one another in varying designs. The method, however, is tedious and requires careful work, and is, therefore, expensive.

(To be continued.)

"METALLURGIA" CHART, JUNE, 1931.
THE KENNEDY PRESS, LTD.,
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and supplied in the hard-rolled, half-hard, medium, soft,
conditions.

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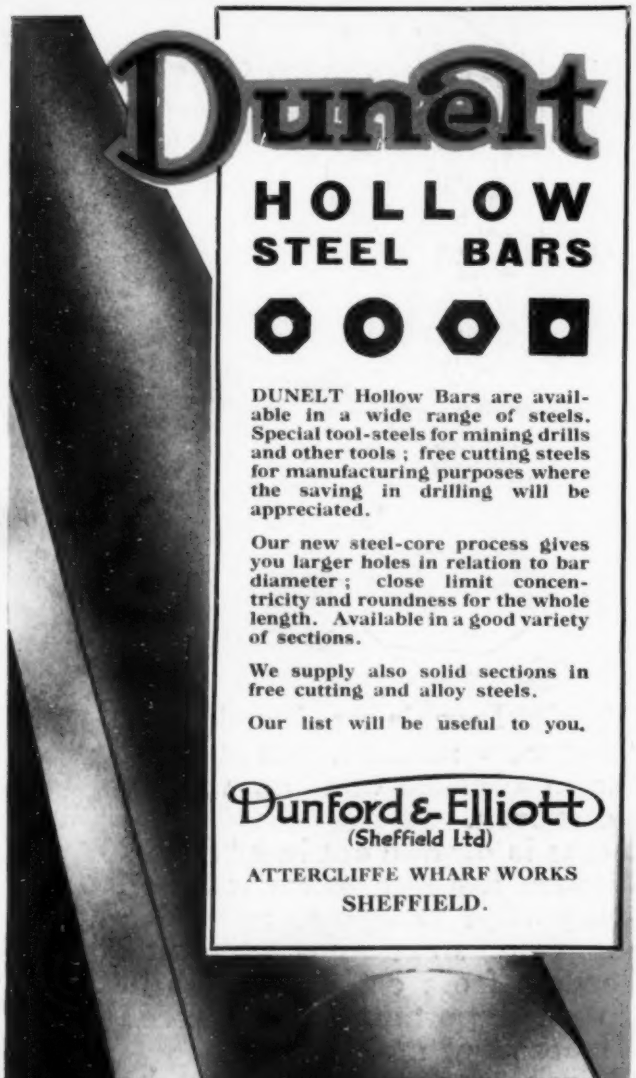
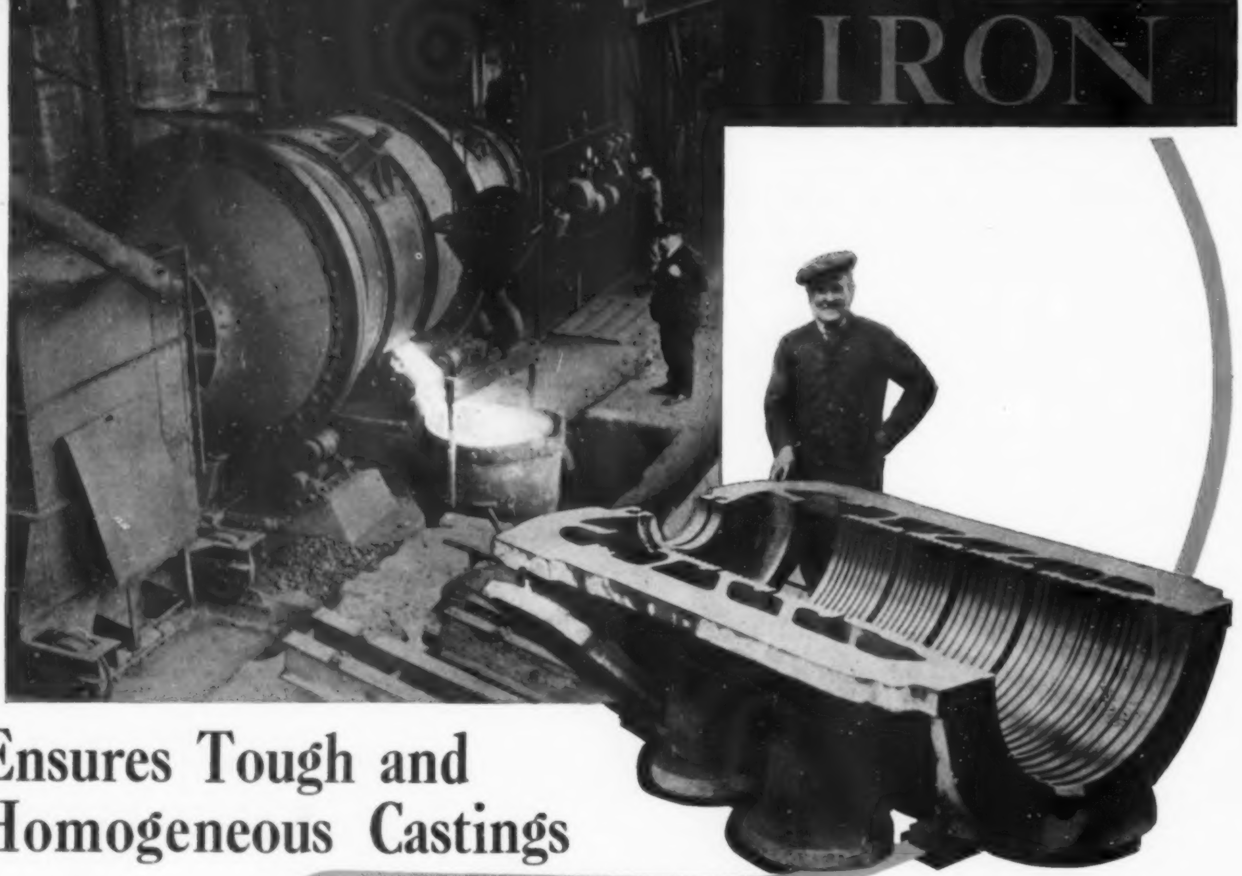


NEW PROCESS IRON



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The melting process is carried out in a "Sesci" Rotary Type Furnace fired by pulverised fuel, resulting in a very high temperature which ensures the complete solution of graphite. Furthermore, freedom from occluded gases in the metal is also an important feature made possible by this method of melting.

"New Process" iron was employed for the Turbine casting illustrated and the accompanying test figures indicate clearly its remarkable properties.

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— 19,2 tons per sqr. inch.

Transverse Test
on 36 inch centres, 2 inch by 1 inch section, 1.84 tons with a deflection of 0.46 inch.

Transverse Test
at 12 inch centres on a 2 inch by 1 inch section bar, 6.44 tons with a 0.13 inch deflection.

Transverse Test
on 12 inch centres 1 inch by 1 inch section, 2.18 tons with a deflection of 0.12 inch.

A tensile strength of at least 24 tons per square inch can be attained on simpler forms ot casting, using this refined pig iron, which is especially suitable for Diesel and high speed internal combustion engineering work.

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CLOSE WORKS GATESHEAD-ON-TYNE

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The Surface Treatme

Chemical Methods of Surface

IN all chemical methods, if aluminium alloys and not the pure metal are being treated, due consideration must be given to the nature of the alloys. Treatment under these methods may be broadly classified under pure chemical, physico-chemical, and electro-chemical processes, each being subdivided according to the form of treatment desired.

PURE CHEMICAL PROCESSES.

ORNAMENTAL FINISHING—MATTING OR FROSTING.—A matt or frosted finish on aluminium is produced by dipping the metal first in an alkaline and then in an acid pickle, the latter being necessary to remove the black deposit which the alkaline dip generally produces. The alkaline pickle is usually caustic soda, of strength not less than 10% by weight, at a temperature of about 95° C. Two cold-water rinses are necessary before dipping in the acid bath, which consists of a mixture of acids, sulphuric and phosphoric (9 : 1)—about 2% by weight,—or in cases where the black scum is not readily removed, sulphuric and nitric (1 : 1) of greater strength. The metal has then to be thoroughly rinsed, first with cold and then with hot water, and dried with hot sawdust

IMMERSION PROCESSES—COLOURING.—By colouring is meant here not the strictly chemical sense of the word ; for aluminium this is impossible, as no coloured compounds of aluminium exist, and the " colouring " is therefore dependent on the presence of other metals—copper, nickel, iron, etc. Most of the processes devised do not come under the pure chemical heading, being dependent either on electrolytic deposition of the colour-giving metal, or on an anodic production of an oxide film, which is subsequently dyed, either with aniline dyes for indoor service, or mineral colours (cobalt salts, etc.) for outdoor service. The methods which may be called chemical belong to the group of chemical immersion processes.

A dead-white coating can be given to aluminium by boiling it in "milk of lime" which contains a little $CaSO_4$, and subsequently baking. The coating adheres very firmly, and is not removed on bending ; it cannot be rubbed off by the fingers, but a pencil eraser removes it. The texture is extremely fine-grained, and the surface can be enamelled or painted, or sized if required for ink.[2]

The Jirotka process for producing a coloured film on aluminium by immersion in a bath of an aqueous solution of chromates, etc., and salts has been in use for some time, and a recent patent[3] provides a modification, the bath consisting of chromates or dichromates, or both, in alkaline solution with, or without, additions of metallic salts. The action of the alkali is to dissolve away the aluminium to a certain depth, the chromate then producing a uniform dispersion of the alloying constituent exposed.

Various baths have been compounded to give a black finish, some of the solutions being very complex. The following methods are typical :—

(*a*) The surface is treated with copper-ammonium chloride, and heated to produce copper oxide. The surface is subsequently treated with sodium sulphide, or lamp black is rubbed in.[4]

(*b*) Bath treatment is given with nickel sulphate, 10 g. ; sod. fluosilicate, 5 g. ; pot. nitrate, 25 g. ; water, 2 litres.

(*c*) The surface is treated with ammonium molybdate.[5]

(*d*) Bath treatment is given with tannin, and the metal is heated gently ; the finish imparted is dull black.

(*e*) After an acid dip in 3 : 1 H_2SO_4 the metal is treated with a mixture consisting of 150 gr. antimony bichloride, 100 gr. manganese nitrate, 20 gr. graphite, and 250 gr. HCl in 1 litre 90% alcohol. It is then coated with a varnish made up of 50 gr. sandarak and 100 gr. nigrosin in 1 litre spirit.

2 Westinghouse Electrical and Manufacturing Co.
3 Pacz. E.P. 338,204.
4 British Aluminium Co.
5 F. A. Roux, U.S.P. 1,095,357.

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6 J. A. Haslip.
7 M. O. Herchmann. U.S.
8 O. F. Reinhold. U.S.P.
9 British Thompson-Housto
10 E. Michel. U.S.P. 1,754,
11 C. Boulanger. E.P. 342,
12 Cournot and Perot.

nent of Aluminium and its Allo

rface Protection are Classified According to Treatment Desired

e" finish can be given to aluminium by the following method. The lacquered with gum lacquer, and is then supported over a smoky gas oling, the surface is treated with boiled-linseed oil.

dised" finish, which makes aluminium resemble oxidised silver, is lipping in a bath containing 2 oz. arsenic, 1 oz. iron sulphate, 2 oz. copper gal. HCl (the specific gravity of the bath should be about 1.115 (15° Be)).[6]

process, registered under the name of "Panalumin," which depends on t, may be applied to produce coloured surface effects.

N PROCESSES—METAL PLATING.—The methods of non-electrolytic er metals on aluminium depend again on the use of special baths; they mber.

A copper coating may be produced by treating with boiling copper hort time and washing and treating with a boiling bath of concentrated te for 15–30 minutes. The articles must be transferred rapidly between baths, and not exposed for any length of time to the atmosphere.

n in a mixed solution of copper sulphate and acetate also produces a g.[7]

luminium plates are coated with lead chlorides and urea. When this ted on the aluminium the lead forms a firmly adherent coating in which m which penetrates the coating is rendered passive and not readily

N PROCESSES—OXIDISING.—A recent patent[9] has been applied for cess of producing an oxide film on aluminium by immersion in an aqueous alkali together with a catalyst, with or without ammonia. A suitable is 2–6% NaOH, 1.5–3% ammonia, and 2.5–12% of a catalyst, preferably e.

N PROCESSES—MISCELLANEOUS.—A number of special processes have out from time to time to provide for the surface protection of aluminium coatings, frequently of a complex nature. Some examples are:—

metal surface is treated with a lac or varnish with a synthetic-resin base g free phenol. The phenol attacks the metal and produces a protective [10]

luminium is immersed in a boiling bath containing a vanadate, molybdate, nate, uranate, niobate, manganate, etc., or a mixture of these salts, and rbonate or the corresponding alkali hydroxide. The process is patented ler the trade name of "Protalisation."[11]

er bath formula consists of a 1.5% solution of equal parts of pot. ustic soda, and alum. (The bath is used at 90–95° C.)

alkaline bath treatment is sometimes used; one such bath consists of carbonate, 25 grms. sod. bicarbonate, and 10 grms. pot. bicarbonate, in and is used hot.

PHYSICO-CHEMICAL METHODS.

N PROCESSES.—Some experimental work has been carried out to obtain nc on aluminium by heating in contact with a suitable mixture, but the ot yet passed the laboratory stage.

TION.—A process exists ([12]) for the cementation of aluminium by copper. first deposited on the aluminium (by electrolytic or other means), and is the electric furnace in a neutral atmosphere. No appreciable cementation takes place below 544° C. (the forma solution), and for any appreciable p the m.p. of aluminium

OXIDATION BY HEATING.—Simp aluminium and its alloys, and heati cadmium coatings on aluminium to

ELECTRO-C

Most of the important methods on electro-chemical processes.

ANODIC OXIDATION.—When alu it becomes coated with a uniform, f structure of the film contains fine p theoretically, the process may be con but according to recent work on the practical limit (in the region of 70 equal current density over the wh uniform.

Different explanations have been oxide:—*Chemical*, that aluminium tates the hydroxide; *Electro chemi* anode of oxygen, which combines hydroxide formation; *Electrical*, i undergoing a breakdown effect, g and harden the hydroxide, even aluminium oxide.

Anodic treatment is applicabl except those with a copper conte heat-treated or aged or in the a depend on the use of different el

(*a*) *Bengough's Method.*—The solution. The voltage kept at 40 for 35 min at 50 for five minute

(*b*) *Stafford O'Brien Method.*—

(*c*) *Jirotka Method.*—The ele

(*d*) *Setoh and Miyata Method* In this method the an pitted if the circulati overcome by superim alternating voltages

The choice of method and t for which the metal is required. purposes, and the process of Seto If the oxide film is required to be tion of a suitable paint, enamel, o increased by treatment with supe insulation the film is thereby re

A new process of electric ox Aluminium Werke, Eloxal. Det insulation has a much greater ra to 10,000 volts being producib resistant in addition.

mann. U.S.S.R.P. 39,783.
ld. U.S.P. 1,362,739 (1921).
pson-Houston Co. E.P. App 20,802 (1930).
U.S.P. 1,754,481.
. E.P. 342,256 (1929).
Perot.

urface Treatment of Aluminii

Chemical Methods of Surface Protection are Classified According to

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re spirit.

A "smoke" finish can be given to aluminium by the following method. metal is first lacquered with gum lacquer, and is then supported over a smoky flame. On cooling, the surface is treated with boiled-linseed oil.

An "oxidised" finish, which makes aluminium resemble oxidised silv produced by dipping in a bath containing 2 oz. arsenic, 1 oz. iron sulphate, 2 oz. c sulphate in 1 gal. HCl (the specific gravity of the bath should be about 1.115 (15°

A trade process, registered under the name of "Panalumin," which depen bath treatment, may be applied to produce coloured surface effects.

IMMERSION PROCESSES—METAL PLATING.—The methods of non-electr plating of other metals on aluminium depend again on the use of special baths; are few in number.

Copper.—A copper coating may be produced by treating with boiling c nitrate for a short time and washing and treating with a boiling bath of concent copper sulphate for 15–30 minutes. The articles must be transferred rapidly bet the different baths, and not exposed for any length of time to the atmosphere

Immersion in a mixed solution of copper sulphate and acetate also produ copper coating.[7]

Lead.—Aluminium plates are coated with lead chlorides and urea. When mixture is heated on the aluminium the lead forms a firmly adherent coating in any aluminium which penetrates the coating is rendered passive and not re oxidisable.[8]

IMMERSION PROCESSES—OXIDISING.—A recent patent[9] has been applie to cover a process of producing an oxide film on aluminium by immersion in an aq solution of an alkali together with a catalyst, with or without ammonia. A sui bath is given as 2–6% NaOH, 1.5–3% ammonia, and 2.5–12% of a catalyst, prefe sodium silicate.

IMMERSION PROCESSES—MISCELLANEOUS.—A number of special processes been brought out from time to time to provide for the surface protection of alumi by producing coatings, frequently of a complex nature. Some examples are:—

(1) The metal surface is treated with a lac or varnish with a synthetic-resin and containing free phenol. The phenol attacks the metal and produces a prote layer or crust.[10]

(2) The aluminium is immersed in a boiling bath containing a vanadate, molyb tungstate, titanate, uranate, niobate, manganate, etc., or a mixture of these salts an alkaline carbonate or the corresponding alkali hydroxide. The process is pat in France under the trade name of "Protalisation."[11]

(3) Another bath formula consists of a 1.5% solution of equal parts of dichromate, caustic soda, and alum. (The bath is used at 90–95° C.)

(4) Mild alkaline bath treatment is sometimes used; one such bath consis 25 grms. pot. carbonate, 25 grms. sod. bicarbonate, and 10 grms. pot. bicarbona 1 litre water, and is used hot.

PHYSICO-CHEMICAL METHODS.

DIFFUSION PROCESSES.—Some experimental work has been carried out to o a coating of zinc on aluminium by heating in contact with a suitable mixture, bu process has not yet passed the laboratory stage.

CEMENTATION.—A process exists ([12]) for the cementation of aluminium by co The copper is first deposited on the aluminium (by electrolytic or other means), a then heated in the electric furnace in a neutral atmosphere. No appreciable cement

6 J. A. Haslip.
7 M. O. Herchmann. U.S.S.R.P. 39,783.
8 O. F. Reinhold. U.S.P. 1,362,739 (1921).
9 British Thompson-Houston Co. E.P. App 20,802 (1930).
10 E. Michel. U.S.P. 1,754,481.
11 C. Boulanger. E.P. 342,256 (1929).
12 Cournot and Perot.

nium and its Alloys

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takes place below 544° C. (the formation temperature of the eutectic Al_2Cu in solid solution), and for any appreciable penetration the heating must increase to nearly the m.p. of aluminium

OXIDATION BY HEATING.—Simple heating in air produces a thin oxide film on aluminium and its alloys, and heating to 100–200° C. has been applied to zinc and cadmium coatings on aluminium to give rise to the formation of oxide films.

ELECTRO-CHEMICAL METHODS.

Most of the important methods of surface treatment of aluminium are dependent on electro-chemical processes.

ANODIC OXIDATION.—When aluminium is made the anode in a suitable electrolyte it becomes coated with a uniform, fine-textured, hard, and adherent oxide film. The structure of the film contains fine pores, allowing the passage of the current, so that, theoretically, the process may be continued to produce a film of any required thickness ; but according to recent work on the thickness of the film in relation to breakdown, a practical limit (in the region of $70\,\mu$) exists, above which the pores do not allow of equal current density over the whole surface, the film consequently being no longer uniform.

Different explanations have been given of this formation by electrolysis of aluminium oxide :—*Chemical*, that aluminium goes into solution in nascent hydrogen and precipitates the hydroxide ; *Electro chemical*, depending on the nascence at the (aluminium) anode of oxygen, which combines with the hydrogen generated, hence giving rise to hydroxide formation ; *Electrical*, in that the gaseous films forming are continually undergoing a breakdown effect, giving rise to temperatures sufficiently high to age and harden the hydroxide, even to the extent of forming ultimately a crystalline aluminium oxide.

Anodic treatment is applicable not only to aluminium but to most of its alloys except those with a copper content of more than 5%, and the metal may be either heat-treated or aged or in the anneal condition. The modifications of the process depend on the use of different electrolytes.

(*a*) *Bengough's Method.*—The electrolyte is in this case 3% aqueous chromic-acid solution. The voltage is raised from zero to 40 in the first 15 minutes, kept at 40 for 35 minutes, raised to 50 in the next five minutes, and kept at 50 for five minutes.

(*b*) *Stafford O'Brien Method.*—The electrolyte is a solution of a chloride in H_2SO_4.

(*c*) *Jirotka Method.*—The electrolyte is a solution of HNO_3 of not less than 25%.

(*d*) *Setoh and Miyata Method.*—The electrolyte is a dilute solution of oxalic acid. In this method the anode metal (the aluminium) has a tendency to become pitted if the circulation of the electrolyte is not perfect ; this difficulty is overcome by superimposing a.c. to d.c. during electrolysis and adjusting the alternating voltages suitably.

The choice of method and the conditions of treatment are governed by the use for which the metal is required. The English processes are generally used for protective purposes, and the process of Setoh and Miyata is generally used for electric insulation. If the oxide film is required to be protective, it is much improved by subsequent application of a suitable paint, enamel, or grease. The ageing and deposition of the oxide can be increased by treatment with superheated steam for protective purposes, but for electrical insulation the film is thereby rendered too brittle.

A new process of electric oxidation has recently been developed by the Vereinigte Aluminium Werke, Eloxal. Details of the method are not available, but the electric insulation has a much greater range than with other methods, a dielectric strength up to 10,000 volts being producible. The coating is extremely hard and chemically resistant in addition.

(*To be Continued.*)

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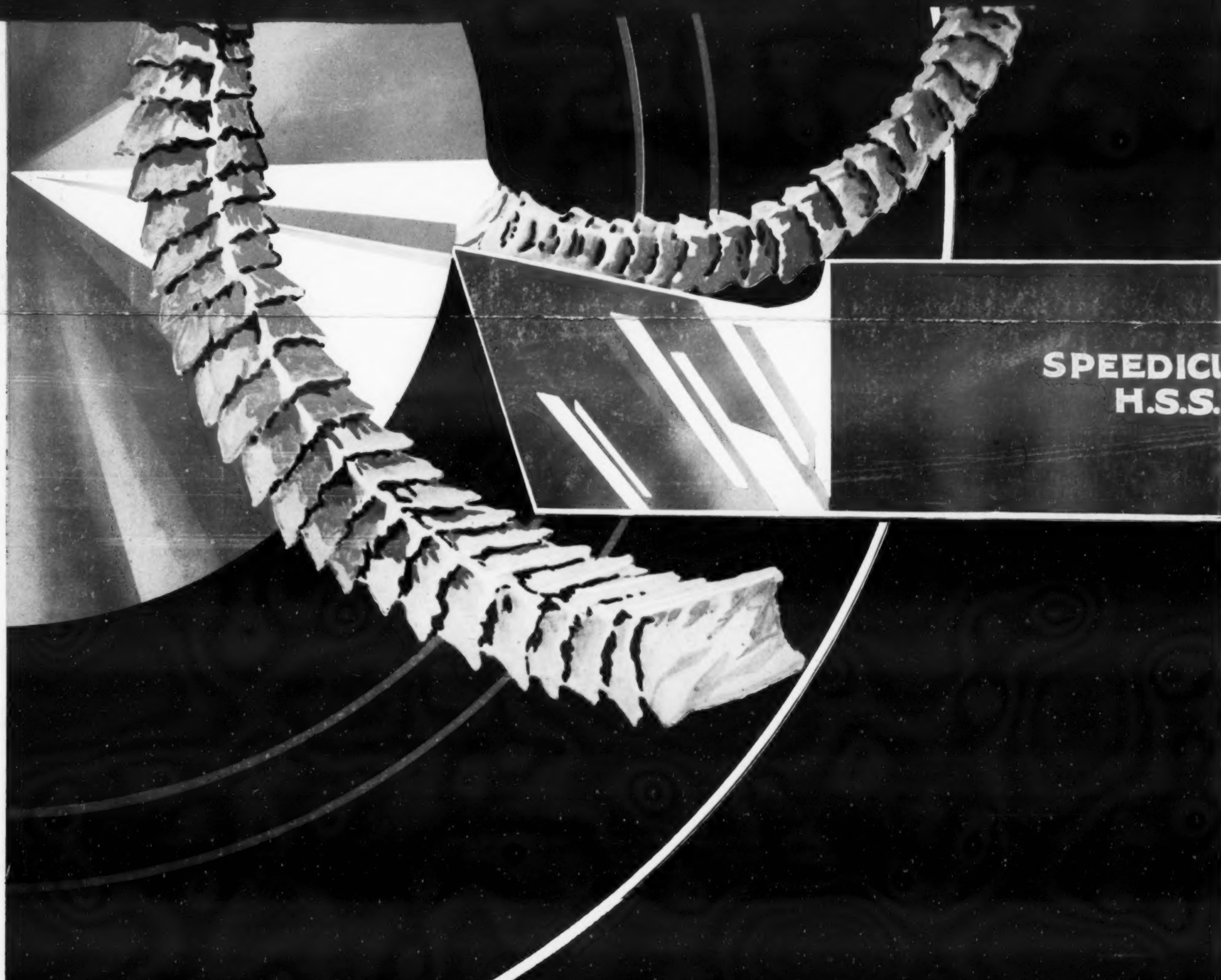

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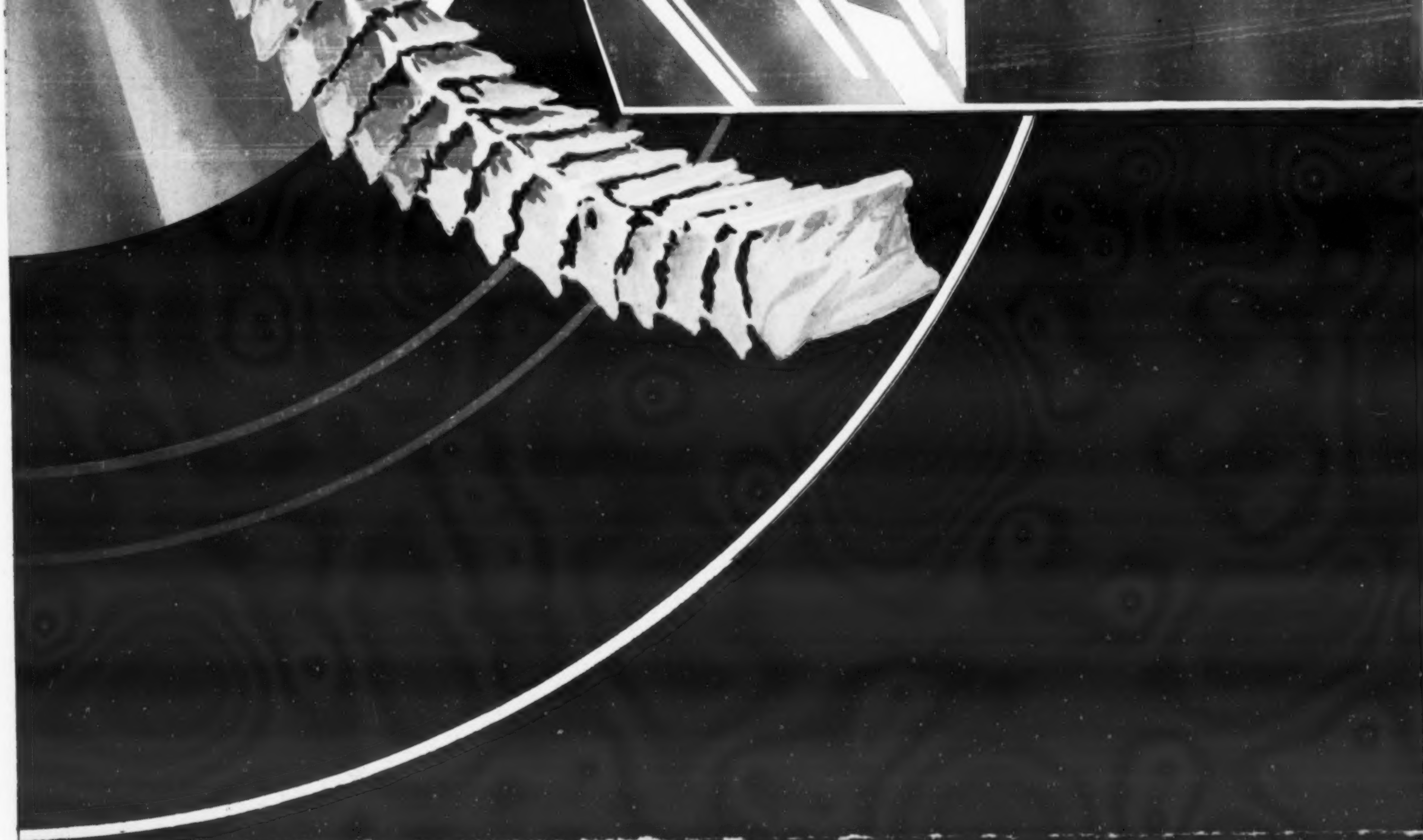

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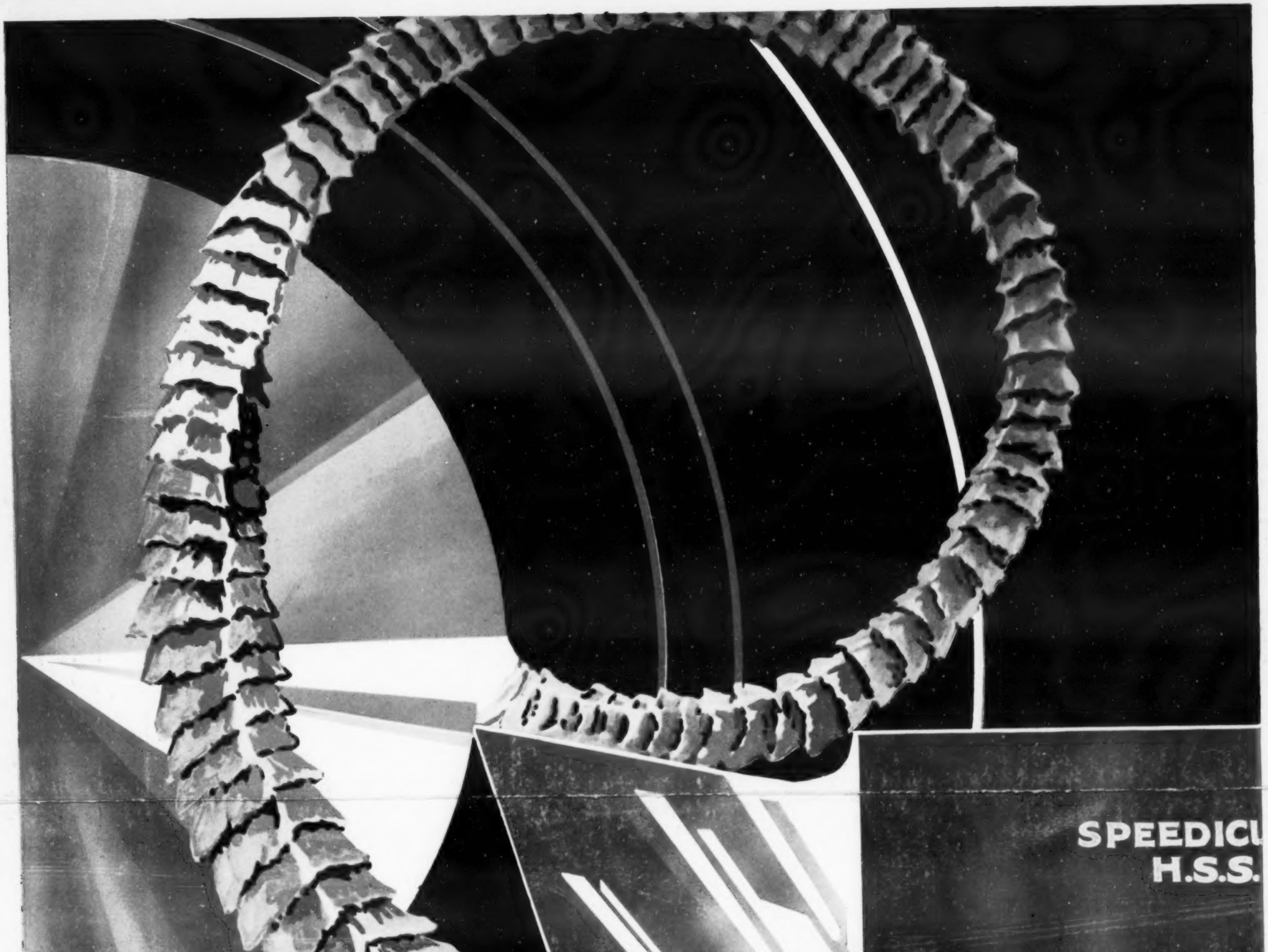
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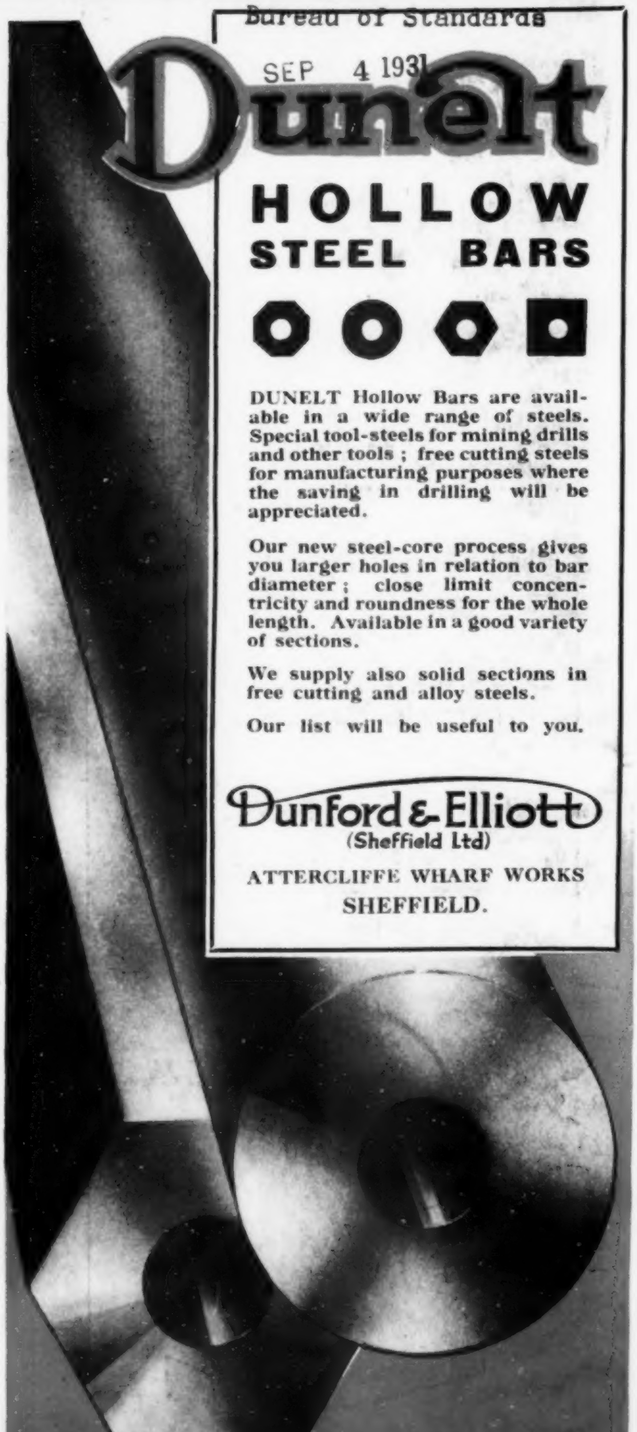
THE BRITISH JOURNAL OF METALS.

Bureau of Standards
SEP 4 1931



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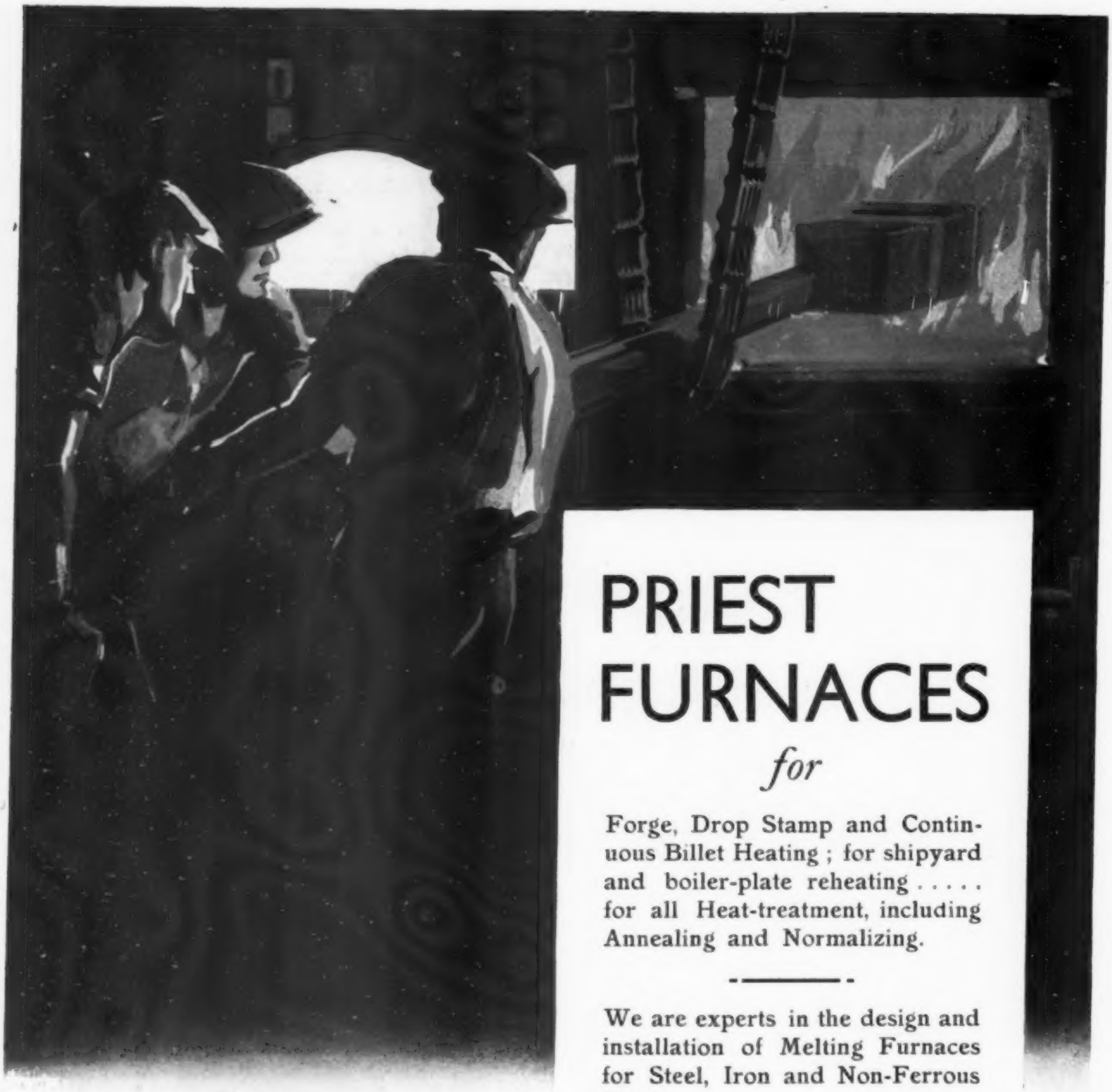

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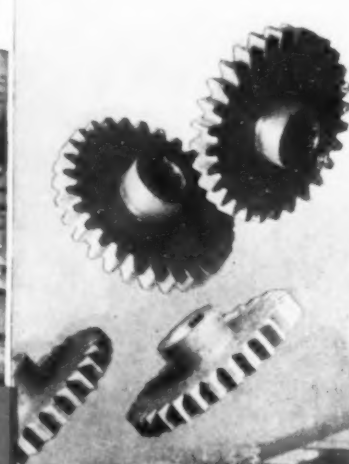

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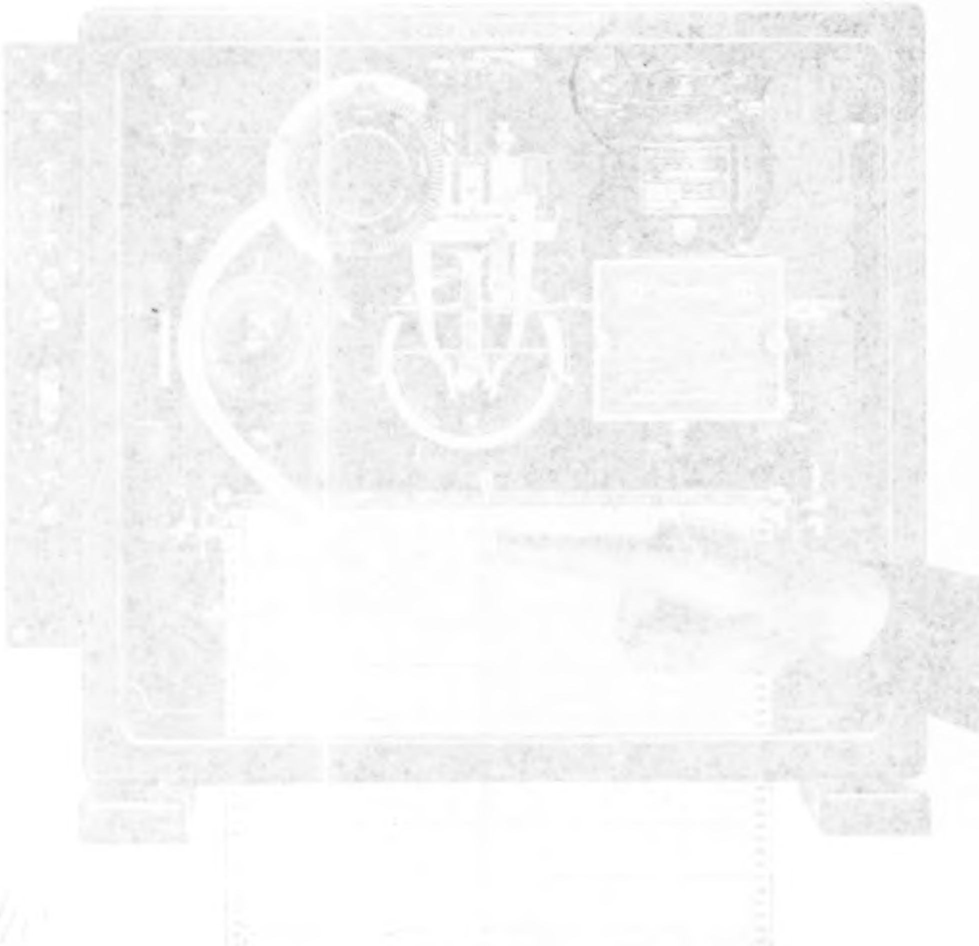

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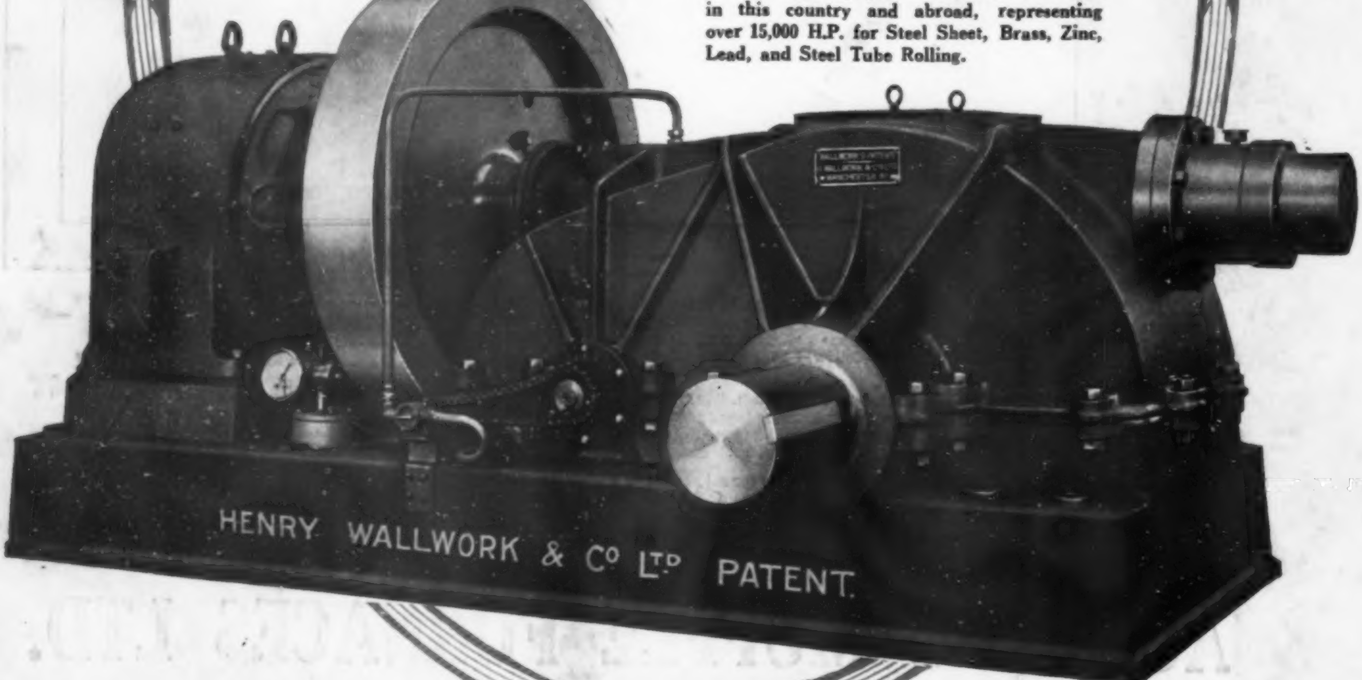

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